JUDITH MEHTA, CHRIS STARMER AND ROBERT SUGDEN

FOCAL POINTS IN PURE COORDINATION GAMES: AN EXPERIMENTAL INVESTIGATION

ABSTRACT. This paper reports an experimental investigation of the hypothesis that in coordination games, players draw on shared concepts of salience to identify 'focal points' on which they can coordinate. The experiment involves games in which equilibria can be distinguished from one another only in terms of the way strategies are labelled. The games are designed to test a number of specific hypotheses about the determinants of salience. These hypotheses are generally confirmed by the results of the experiment.

Keywords: Common knowledge, multiple equilibria, focal points, salience, coordination games.

0. INTRODUCTION

This paper is concerned with an approach to game theory which derives from Schelling (1960). Schelling argues that in games with multiple Nash equilibria, one equilibrium often stands out from the others – is *salient* – in virtue of some property which all the players can recognise. Such an equilibrium is a *focal point*. Each player then chooses the strategy corresponding with the focal point in the expectation that the others will do the same.

We may distinguish between the *mathematical structure* of a game and its *labelling*. For the purposes of this paper, the mathematical structure of a game will be taken to be the normal form. Any presentational features which are not entailed by the mathematical structure of a game, such as the names given to players and strategies, constitute the labelling of that game. In conventional game theory, analysis is confined to the mathematical structure of a game; if two games differ only in respect of labelling, they are treated as isomorphic (e.g. Harsanyi and Selten, 1988, pp. 70–74). According to Schelling, however, the properties which make an equilibrium salient are often properties of labelling, and derive their significance from relationships between the labels and the common experience or common culture of the players. Since such properties are invisible in the mathematical structure of a game, they resist conventional game-theoretic analysis.

Theory and Decision **36**: 163–185, 1994.

We report an experimental investigation of a class of games in which the only properties that can distinguish one equilibrium from another are properties of labelling. The experiment is the first step in a larger programme of developing a theory of focal points. At this stage, our aim is to formulate provisional hypotheses about the determinants of salience, and to test these hypotheses in controlled experiments.

1. FOCAL POINTS

The significance of focal points can be illustrated most clearly in *pure coordination games*. These are games in which there is no conflict of interest: both players merely want to coordinate, and are indifferent between the alternative ways in which they might do so. As an example, consider the following pure coordination game, which we shall call Heads and tails. Two players who are unable to communicate are each asked to name either 'Heads' or 'Tails'. They both know that they will be rewarded for coordinating their strategy choices, and each knows that the other is also trying to coordinate. In normal form, this game may be represented as follows:

		Player B: Heads	Player B: Tails
Player A	Heads	1, 1	0, 0
	Tails	0, 0	1, 1

There are three Nash equilibria in this game: two pure strategy equilibria (Heads, Heads) and (Tails, Tails), and a mixed-strategy equilibrium in which each player plays each strategy with probability 0.5. The two pure strategy equilibria, each yielding payoffs of $(1, 1)$, are better for both players than the mixed strategy equilibrium, which yields expected payoffs of $(0.5, 0.5)$.

The standard approach is to treat the utility entries in the payoff matrix as providing all the information that rational players need in order to make decisions. On this view, the labels attached to strategies are irrelevant. For example, it would make no difference to the analysis of the game we have just presented if the strategies were labelled x and y rather than 'Heads' and 'Tails'. In this context, characteristics of strategies which relate to the spatial layout of the matrix (such as 'top' and 'bottom', 'left' and 'right', and 'row' and 'column') are also matters of labelling, and thus of no relevance to the decision-making of rational players.

In Heads and Tails, the two strategies of each player are entirely symmetrical with one another: there is no way of distinguishing between these strategies without referring to their labels. Thus, if labels are irrelevant, rational players of the game must be indifferent between their strategies. Given this conclusion, there seem to be no grounds for expecting a player to be more likely to play one strategy rather than another, or for expecting any correlation between the strategy choices of the two players. The natural conclusion to draw is that, for 'rational' players who treat labels as irrelevant, the probability of achieving coordination in Heads and Tails is 0.5.

However, ordinary human players seem to be capable of achieving much greater degrees of coordination than this. Schelling (1960, pp. 54–58) reports some informal experiments with pure coordination games, including Heads and Tails. In the case of Heads and Tails, 36 out of 42 respondents chose Heads. Thus, if you were playing someone drawn at random from Schelling's sample and if you played Heads, you would have an 86 per cent chance of success. In an environment of people following the recommendations of rational choice theory, in contrast, your chance of success would be only 50 per cent, irrespective of how you played. The majority of Schelling's respondents apparently expected others to choose Heads, and they were right. So how did they succeed where rational choice theory would fail?

Schelling (p. 64) suggests that Heads has "some kind of conventional priority" over Tails, and that his respondents knew, or guessed, that this was so. This piece of common cultural knowledge provided them with the clue they needed to coordinate: it made (Heads, Heads) the focal point of the game. Notice that, on this analysis, the players use a clue provided by the *labelling* of the strategies to connect the game with something in their common experience: the conventional priority of Heads over Tails. But since rational choice theory treats the labels as irrelevant, it cannot explain how coordination could emerge, other than by chance. Schelling goes on to show that a similar analysis can be applied to other games with multiple equilibria, including games in which there is a conflict of interests.

Schelling's approach is often discussed by game theorists, but relatively little has been done to develop or test a theory of how the labelling of strategies generates focal points. Some significant theoretical steps have, however, been made by Gauthier (1975) and Bacharach (1991); more will be said about these in Section 2. There has also been some experimental investigation of the significance of labelling in bargaining problems (e.g. Roth and Murnighan, 1982). But most theoretical work on equilibrium selection has taken the unlabelled, mathematical structure of games as its datum, and has looked for principles which would distinguish particular equilibria within this structure (e.g. Harsanyi and Selten, 1988). Experimentalists have then investigated the extent to which people act on various principles of this kind (e.g. Cooper *et al.*, 1990; Van Huyck *et al.*, 1990). This kind of approach can yield results if there are asymmetries between strategies which show up in the mathematical structure of a game, but it cannot explain how asymmetries of labelling generate focal points when strategies are mathematically symmetrical. Some theorists have made further progress by investigating the implications of pre-play communication (Van Damme, 1989; Ponssard, 1990), repetition (Crawford and Haller, 1990) and evolution (Crawford, 1991; Kandori *et al.*, 1993; Young, 1993) for equilibrium selection in unlabelled coordination games. Although important in their own right, these lines of enquiry do not address the issue posed by Schelling's experiments: how does the labelling of strategies, independently of any properties of the mathematical structure of a game, enable players to identify focal points?

If the results of Schelling's informal experiments can be replicated, there is a regularity in human behaviour which requires an explanation: players of one-shot pure coordination games are able, without any pre-play communication, to distinguish between mathematically symmetrical strategies in a way that enables them to coordinate their choices. Even if pure coordination games were never played outside experimental laboratories, this regularity would be of great interest. In every real-world interaction that game theory models, strategies have labels, and these labels have the potential to influence players' choices. If game theory is intended to yield predictions about human behaviour, then it is important to know how far players are in fact influenced by labels. If instead one sees game theory as a normative analysis of the implications of rationality, Schelling's results are interesting for a different reason. These results suggest that the players of pure coordination games may be using some mode of reasoning which lies outside the domain of the conventional theory of rational choice, but which enables them to achieve their ends more effectively than can the rational agents of that theory. This raises fundamental questions about the normative status of the conventional theory. There is a considerable philosophical literature on these issues (see, e.g., Lewis, 1969, pp. 24–36; Gauthier, 1975; Heal, 1978; Gilbert, 1989a, 1989b; Sugden, 1991, 1993), but the discussion is constrained by the limited state of current knowledge about how people reason about coordination games.

If we are to investigate the significance of labelling, one-shot pure coordination games provide a natural starting point. The mathematical structure of these games provides players with no way of distinguishing between strategies. And since this mathematical structure is extremely simple, it offers players a minimum of opportunities for misunderstanding it. Thus if an experiment with such games has been appropriately controlled, it is legitimate to attribute any observed asymmetries in players' strategy choices to the effects of labelling.

2. SOME DETERMINANTS OF SALIENCE

When one explains coordination in terms of 'salience', there is a danger that one is providing nothing more than an *ex post* rationalization. For example, Schelling explains his respondents' choice of Heads in Heads and Tails by suggesting that Heads has conventional priority over Tails. But if the majority of respondents had chosen Tails, it might have been possible to offer an equally plausible account of why Tails was salient. If a theory of focal points is to have genuine explanatory or predictive power, it must be capable of generating falsifiable hypotheses. One way in which such a theory might be developed is by investigating the determinants of salience. This is the strategy pursued in this paper. Our experiment was designed to test some preliminary hypotheses about salience.

In forming our hypotheses, we began from a remark of Schelling's (1960, p. 94). As part of his discussion of pure coordination games, Schelling describes a game in which each of two players is instructed to name any positive number, each being rewarded if they name the same number. According to Schelling, "the predominant choice is the number 1". (It seems that he has carried out an informal experiment with this game, but he does not report the results.) As an explanation of this result, he suggests that players ask themselves "*what rule of selection would lead to unambiguous results*", and that their answers to this question lead them to choose the number 1. The idea seems to be that players can recognise a set of *rules of selection*, each of which could be used to choose from the positive numbers – for example, 'Choose an even number', 'Choose the first number which comes to your mind', or 'Choose the smallest number'. Each player then looks for a rule within this set which, if followed by both players, would be very likely to lead them both to choose the same number. If one and only one such rule exists, or if more than one rule exists but all imply the choice of the same number, the number chosen by that rule (or those rules) is the focal point of the game. In the game of naming a positive number, Schelling suggests that the least ambiguous rule is 'Choose the smallest number'. Gauthier (1975) and Bacharach (1991) have developed this suggestion by proposing formulations of the concept of a rule of selection that are relevant for certain kinds of coordination games. Gauthier and Bacharach argue that if there exists some rule which, if followed by both players, would give each player a higher expected utility than would any other rule, then it is rational for each player to follow it. Our hypotheses about focal points are based on a similar kind of reasoning.

We focused on a particular class of pure coordination games, which we shall call *assignment games*. In an assignment game, two players are presented with a set of objects of some type A, and with two objects B_1 and B_2 of a different type. The players are instructed to assign each A-object to one or other of the B-objects; each is rewarded if they choose the same assignment.

We postulated three rules of selection which seemed to us to be particularly likely to be recognised by the players of assignment games. This list is not intended to be exhaustive. At this stage, we are not trying to formulate a comprehensive theory of salience. Our immediate objective is more modest: to isolate a small number of rules of selection that can be used to generate hypotheses which can then be tested in controlled experiments.

i. *The rule of closeness*. This rule emerges from mutual recognition of a metric of proximity, or closeness of association, between *A*s and *B*s. The rule assigns each *A* to the *B* to which it is closer. 'Closeness' need not be understood as a spatial relation in the literal sense; it might, for example, be interpreted in terms of colour, time, or kinship.

ii. *The rule of accession*. This rule is a two-step variation on the rule of closeness. It emerges from mutual recognition of a metric of proximity or association between *A*s. The rule requires that if a set of *A*s are closely related to one another, this set should not be broken up; the set as a whole should be assigned to the *B* to which it is closer.

iii. *The rule of equality*. If there is an even number of *A*s, half of them should be assigned to one *B* and half to the other. Given our definition of an assignment game, in which it matters *which* *A*s are assigned to each *B*, this rule alone never identifies a unique solution. However, it may identify a subset of assignments, from which one assignment can be chosen by using either the rule of closeness or the rule of accession. For example, from the set of equal assignments, one might choose the one which minimizes the average distance between *A*s and the *B*s to which they are assigned.

In formulating these three rules, we drew on a wide range of ideas. In part we were guided by introspection. We also made use of the analogy between assignment games and those bargaining problems in which a set of valuable objects (slices of pie, in the familiar metaphor) has to be divided between two claimants. (This analogy seems to have been the basis of Schelling's (1960, pp. 54–67) interest in assignment games.) By thinking about the ways in which bargaining problems are conventionally resolved, we were able to come up with some ideas about rules of selection for assignment games. We found further guidance from Schelling's work, and from David Hume's (1740) much earlier analysis of the origins of justice and property.

There are many striking parallels between Hume's analysis and Schelling's.[1] Hume argues that people recognise the advantages to individual self-interest gained from interaction in society. But they also recognise that the major source of conflict in society emanates from goods with the characteristic that they can easily be transferred from person to person. He suggests *convention* has emerged as the means by which such conflicts may be averted: convention enables each person to recognise what others will accept as being his or her property. Hume had the insight that the rules that determine property might be grounded, not in rational calculation of the public interest, but in 'imagination' – in analogy and metaphor. Since the notion of property forms a relation between a person and an object, Hume argues it is natural to found a convention about property on some preceding relation between persons and objects.

Closeness and accession are two such relations, and feature strongly in Hume's account of the origin of property. Principles of closeness are commonly used to resolve bargaining problems. For example, fishing rights in areas of the sea and mineral rights in the sea bed are normally allocated to the country whose coastline is nearest. Closeness need not be a spatial association: for example, 'first possession' (or 'finders keepers') is a standard principle used to settle ownership of an object. Hume (1740, pp. 509–510) presents an engaging example in which a German, a Frenchman and a Spaniard enter a room in which there are three bottles of wine – Rhenish, Burgundy, and port. If they fall into a dispute about who should have which bottle, Hume says, the obvious solution is that each should take the product of his own country: this amounts to using a rule of closeness. Developing an idea of Schelling's (pp. 99–111), Kreps (1990, pp. 424–425) presents a similar example. This is the game of Divide the Cities, to be played (without communication) between a student at Stanford and a student at Harvard. Each player is shown the same list of eleven American cities, on which each city is shown as being worth a certain number of points. The list includes San Francisco, which is 'given' to the Stanford student, and Boston, which is 'given' to the Harvard student. Each player then claims as many of the remaining cities as she chooses. Each player wins points for claiming a city that the other player does not, and loses points for claiming a city that the other player claims too. There is a large bonus for both players if they agree on an exact partition of the cities. This game may be thought of as a cross between an assignment game and a bargaining game. Kreps reports that when he asks Stanford students how they would play, they typically claim the more westerly cities.

Accession, too, is used to resolve disputes between rival claimants. If a person has a recognised claim to one object, she is recognised to have a claim to associated objects. Hume (1740, p. 550) gives the example of the offspring of cattle which are recognised as the natural property of the cattle's owners. A similar idea can be found in Schelling's (1960, p. 62) example of two military commanders, each of whom must decide how much of a tract of land his troops should try to occupy. Each wishes to gain as much ground as possible, but both want to avoid coming into conflict. Schelling suggests that the focal point is found by looking for the most obvious boundary line between the two forces; in his informal experiment, most respondents chose to use a river as the limit of their advance. This amounts to a rule of accession: rivers are being seen as dividing the land into coherent blocks, which are not to be broken up.

The somewhat less Humean principle of equality has often been suggested as a determinant of focal points in bargaining games (Schelling, pp. 60–67; Roth and Murnighan, 1982). In the context of bargaining, the salience of equality might result from shared notions of fairness. Alternatively, however, the rule of equality might emerge from common perceptions of symmetry and balance; if so, then the same common perceptions might serve to identify focal points in assignment games.

3. THE DESIGN OF THE EXPERIMENT

The experiment consisted of a set of twenty pure coordination games. These games were played by 120 subjects in nine sessions. Most of the subjects were Open University students attending a succession of summer schools at the University of East Anglia. Sessions were arranged so that none of the subjects who took part could communicate with subsequent participants. Each subject was randomly and anonymously paired with another subject from the same session, and then that pair played the twenty games. In each game, each player had to choose one response from a set of possible responses (the same set for each player). Subjects were told that they would score one point for each response which was identical to that of their unknown partner. In each session, each member of the pair of subjects with the highest total score was paid £5. Subjects were not told anything about their partners' responses until all twenty games had been played.

The first ten games were similar to ones in Schelling's informal experiments. Each game consisted of the instruction to name some member of a given class. The ten instructions were as follows:

1. Suppose you have to meet the other person somewhere in London. Name a meeting-place.
2. Name a car manufacturer.
3. Write down either 'heads' or 'tails'.[2]
4. Name any year, past, present or future.
5. Name any mountain.
6. Write down either 'man' or 'woman'.
7. Name any British town or city other than London.
8. Name any time of day (e.g. 10.22 pm, 7.00 pm).
9. Name any class of relative (e.g. sister-in-law, uncle).
10. Write down any positive number.

These games were not intended as a formal test of any specific hypotheses about the determinants of salience. Our purpose in including them was to check that Schelling's findings could be replicated. Although these findings have become part of the folklore of game theory, we know of no previous attempt to replicate them in a controlled experimental setting.

The remaining ten games were assignment games, and had a common structure. Each game was presented to subjects in the form of a rectangle marked out into a grid. Each grid contained two squares, a red square to the left of the grid and a blue square to the right. Each grid also contained a number of uncoloured circles, varying in number and position from problem to problem. Subjects were given the following instruction: 'You must assign each circle to one or other of the squares. You should do this by colouring each circle either red or blue with the pens provided. *You must colour in every circle*. If, for example, there are two circles, you may colour one of them blue and the other red; or the other way round; or you may colour them both blue; or you may colour them both red. To score a point all your circles must be the same colour as the other player's.' The ten grids are shown in Figure 1. They are displayed as they were presented to subjects in the experiment, except that the squares seen by subjects were coloured and the circles were not numbered. (We have added the numbers for the purpose of describing results.)

These games were designed to test whether subjects would choose those assignments that could be identified as focal points in terms of the rules of closeness, accession and equality. For the rule of *closeness* to be applicable in an assignment game, there has to be some commonly recognised concept of closeness of association between the two classes of object (the As and the Bs). In the case of our grids, the most obvious and unambiguous measure of closeness of association between a circle (an A) and a square (a B) is the distance between them. Thus we interpret the rule of closeness as: assign each circle to the nearer square.

The rule of *accession* implies that if a set of circles form a coherent group, all the circles in the group should be assigned to the same square. We shall say that two circles are *connected* if they are located at adjacent points in the grid, linked by a horizontal or vertical line, and we shall interpret a 'coherent group' as a set of connected circles. We define the distance between a square and a set of connected circles as the distance between the square and the nearest circle in the set. Then we interpret the rule of accession as the following formula: assign each set of connected circles to the nearer square.

The rule of *equality* suggests the general formula: if there is an even number of circles, assign half of them to one square and half of them to the other square. As stated, this rule never implies a unique assignment of circles to squares. We posit the *median line rule* as a subrule or refinement of the rule of equality, which uses the metric of closeness to discriminate among equal assignments. This rule is: if

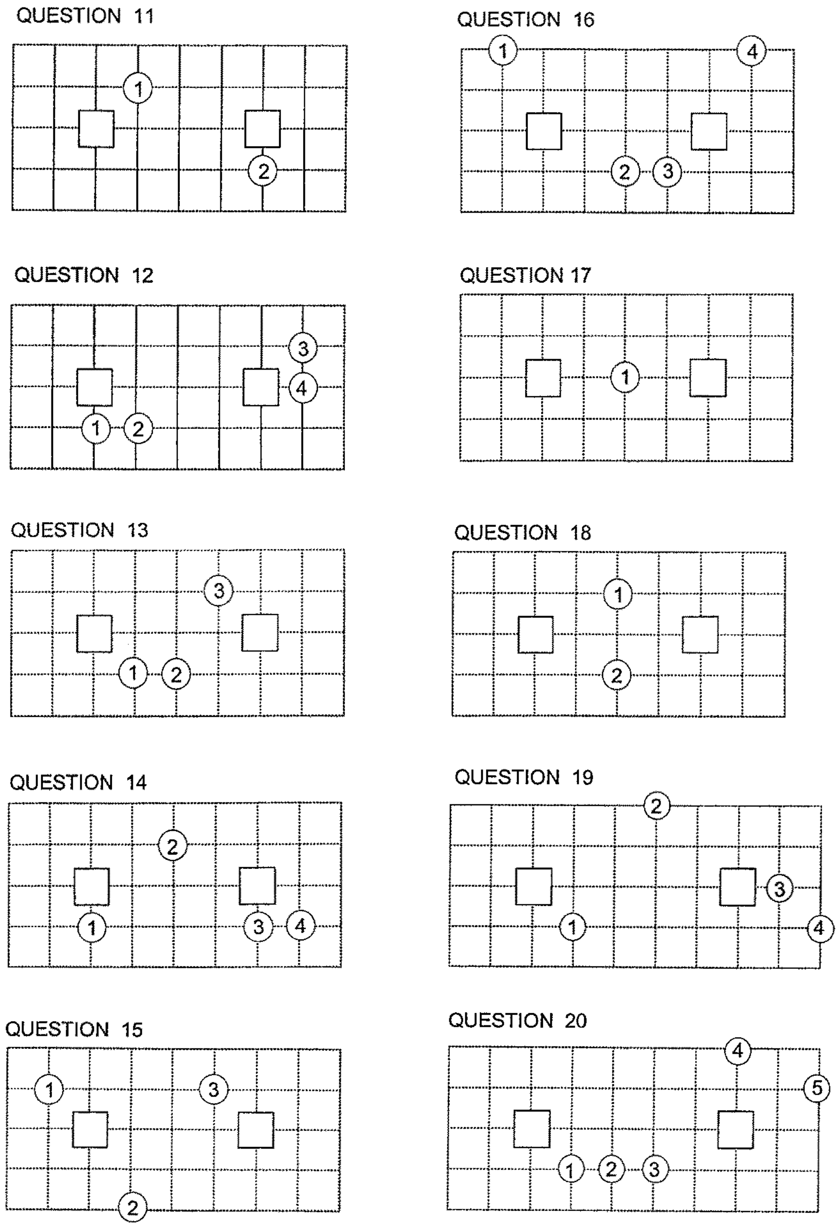

Fig. 1. Diagrams illustrating Questions 11–20.

there is a vertical line such that an equal number of circles lie on each side, then assign circles left of the line to the left-hand square, and circles right of the line to the right-hand square.

Table I sets out the implications of these rules of selection for the ten assignment games. For example, Game 11 allows four assignments. One of these, denoted LR (for 'left, right'), assigns circle 1 to the left hand square and circle 2 to the right hand square; another denoted RL, assigns circle 1 to the right hand square and circle 2 to the left hand one; and so on. Each of the three rules of selection identifies LR as the unique choice. An entry of 'none' denotes that the relevant rule does not identify a unique choice. In Game 17, for example, the rule of equality cannot be applied because there is only one circle; neither the rule of closeness nor the rule of accession implies a unique choice because the circle is equidistant from the two squares.

In forming hypotheses about subjects' behaviour, we assume that these three rules are the only ones that are recognised. There are many rules that might be used in assignment games in general, but in the context of our grids, closeness, accession and equality seemed to us to be by far the most obvious rules of selection. Thus our principal hypothesis was as follows: if some assignment X is the unique choice according to at least one of the three rules of selection, and if no other assignment is the unique choice according to any of those rules, then X

TABLE I

Implications of the three rules of selection.

	unique assignment implied by rule of:			
Game	closeness	accession	equality	predicted responses
11	LR	LR	LR	LR
12	LLRR	LLRR	LLRR	LLRR
13	none	LLR	none	LLR
14	none	none	LLRR	LLRR
15	LLR	LLR	none	LLR
16	none	LRRR	LLRR	LRRR or LLRR
17	none	none	none	none
18	none	none	none	none
19	LRRR	LRRR	LLRR	LRRR or LLRR
20	LLRRR	LLLRR	none	LLRRR or LLLRR

is the focal point of the game. This hypothesis identifies a focal point for each of Games 11–15. In Games 11 and 12, all three rules lead to the choice of the same assignment. This feature of the experiment was deliberate: we did not want to begin the experiment by suggesting that any particular rule of selection was more appropriate than the others. In each of Games 13, 14 and 15, there is at least one rule which implies a unique choice, and there is no conflict between rules.

Such conflicts do occur, however, in Games 16, 19 and 20. In each of these games there are two different assignments, each of which is the unique choice according to at least one rule. In such cases, one might say, there are two focal points. We would expect subjects to choose whichever focal point struck them as more obvious. We had no prior expectations about which focal point would have more appeal in these cases, or about the extent to which subjects would succeed in coordinating their choices. Our hypothesis was simply that most subjects would choose one or other of (what we hypothesized to be) the focal points.

In the remaining two games – Games 17 and 18 – none of the rules identifies a unique choice. We included these games out of open-ended curiosity. It is a recurring theme in Schelling's discussions that people are remarkably resourceful in finding rules that can identify focal points. Games 17 and 18 may be thought of as particularly stiff challenges to this form of reasoning.

4. RESULTS

Subjects' responses to the games are summarized in Table II. For each game, we list all responses that were given by at least 5 per cent of subjects, and show the proportion of subjects who gave each such response. We also show the range of responses in each game (that is, the total number of different responses given by the 120 subjects), and the *coordination index*. The coordination index is a summary statistic devised to indicate subjects' ability to coordinate. Since different random pairings of subjects would result in different numbers of coordinations, we focus on individual responses rather than on coordinations actually achieved. The coordination index measures the probability that two subjects, chosen at random without replacement, give the same response. If there are n subjects, and if each response i is

TABLE II

Results. This table lists each response that was given by at least 5 per cent of subjects. It shows the percentage of the 120 subjects who gave each of these responses, the range of responses (i.e. the number of different responses given), the coordination index (see Section 4), and (for Games 11–20), the number of different responses that were permissible, given the instructions. For Games 11–20, predicted responses (see Table I) are marked by asterisks.

Game 1 (Meeting place in London)	
Trafalgar Square	38
Piccadilly Circus	13
Buckingham Palace	8
Range	28
Coordination index	0.17
Game 2 (Car manufacturer)	
Ford	89
Range	11
Coordination index	0.79
Game 3 (Heads or tails)	
Heads	87
Tails	13
Range	2
Coordination index	0.77
Game 4 (Years)	
1989	71
2000	8
1992	5
Range	16
Coordination index	0.51
Game 5 (Mountains)	
Everest	89
Snowdon	5
Range	5
Coordination index	0.80
Game 6 (Man or woman)	
Man	67
Woman	33
Range	2
Coordination index	0.55
Game 7 (Towns)	
Norwich	59
Birmingham	23
Liverpool	5
Manchester	5
Range	11
Coordination index	0.40
Game 8 (Times of day)	
12.00 noon	28
12.00 midnight	16
10.22 p.m.[a]	5
Range	39
Coordination index	0.11
Game 9 (Relatives)	
Mother	32
Father	20
Brother	17
Sister	8
Sister-in-law[a]	8
Uncle[a]	5
Range	16
Coordination index	0.18
Game 10 (positive number)	
1	29
10	19
2	16
7	8
100	5
Range	19
Coordination index	0.15

TABLE II (*continued*)

Game 11		Game 16	
LR*	74	LLRR*	68
RL	23	RRLL	15
		LRRR*	5
Range	4	Range	10
Possible responses	4	Possible responses	16
Coordination index	0.60	Coordination index	0.49
Game 12		Game 17	
LLRR*	68	L	63
RRLL	9	R	37
LRLR	8		
RLRL	7	Range	3[b]
		Possible responses	2
Range	8	Coordination index	0.52
Possible responses	16	Game 18	
Coordination index	0.47	LR	52
		RL	37
Game 13		LL	6
LLR*	70	RR	5
RRL	11		
		Range	5[c]
Range	8	Possible responses	4
Possible responses	8	Coordination index	0.40
Coordination index	0.50	Game 19	
		LLRR*	45
Game 14		LRRR*	29
LLRR*	68	RLLR	8
RRLL	10	RRLL	6
LRRR	8		
		Range	13
Range	9	Possible responses	16
Possible responses	16	Coordination index	0.29
Coordination index	0.48	Game 20	
		LLLRR*	43
Game 15		LLRRR*	32
LLR*	71	RLRLL	6
RRL	13	RRLLL	5
Range	8	Range	15
Possible responses	8	Possible responses	32
Coordination index	0.52	Coordination index	0.28

Notes

[a] These responses were suggested as examples in the instructions to subjects: see Section 3.

[b] One subject, against instructions, coloured the circle in both colours.

[c] One subject, against instructions, coloured both circles in both colours.

given by n_i subjects, the coordination index is

$$\sum_i \frac{n_i(n_i - 1)}{n(n - 1)}$$

The value of the index ranges from 0 (when every subject gives a different response) to 1 (when all give the same response).

First we consider the responses to Games 1–10. It is clear from a casual inspection of Table II that the distribution of these responses is highly skewed. It seems that subjects are much more successful at coordinating than they would have been if they had answered at random. However, we cannot specify a formal null hypothesis of random responses, since (with the exception of Games 3 and 6) the games were based on open-ended instructions. For example, consider the instruction, 'Name any British town or city other than London'. We do not know the size or contents of the set of British towns that subjects might be able to name; we can only guess that subjects know of a very large number of possible responses, and that the probability of successful coordination would be extremely small if they answered at random. In the two cases in which the number of possible responses is known ('heads' or 'tails', and 'man' or 'woman'), the hypothesis that subjects answer at random can clearly be rejected ($p < 0.001$ in two-tail tests).

In at least some of Games 1–10, subjects seem to be identifying focal points by use of recognisable and general rules of selection. The most common responses in Game 4 ('Name any year, past, present or future') and Game 7 ('Name any British town or city, other than London') are 1989 and Norwich respectively. Given that the experiment took place in 1989, at the University of East Anglia in Norwich, we posit that subjects are drawing on a general rule of the form 'Choose the *status quo*', yielding the formulae 'Choose the current year' and 'Choose the current location'. We may conjecture that, faced with Game 4, subjects ask themselves, 'What year, from the very large universe of years, is unique?' Alternative rules of selection, such as 'Choose the first', 'Choose the last' or 'Choose the most famous', do not lead to an unambiguous result in the same way that the *status quo* rule does.

In Game 5 ('Name any mountain'), 89 per cent of subjects named

Everest, perhaps because Everest ranks first on an obvious scale of comparison for mountains, namely height. Similarly, in Game 10 ('Write down any positive number'), the number 1 is at one extreme of at least two obvious scales of comparison for positive numbers, being both 'first' and 'smallest', while there is no corresponding 'largest', 'central' or 'last' number. And in Game 7 ('Name any British town or city other than London), the most common response after Norwich was Birmingham, which ranks highest on an obvious scale of comparison for cities: population size. In Game 8 ('Name any time of day'), 12.00 noon is the central time of the day, perhaps appealing to ideas of symmetry and balance.[3]

It might be objected that we are merely giving *ex post* rationalizations, inventing *ad hoc* rules of selection to fit the data. We do not believe that this is so, but we must concede that Games 1–10 were not designed to test any formal hypotheses. However, as we have explained in Section 3, Games 11–20 were designed with exactly this purpose. We now turn to the results for these games.

Recall that for five of the ten games (Games 11–15), our hypotheses identify a particular response as a focal point. For a further three games (Games 16, 19 and 20), our hypotheses identify two responses as possible focal points. The responses identified as possible focal points (the *predicted responses*) are marked by asterisks in Table II. With only one exception (the response suggested by the rule of accession in Game 16), predicted responses are always given more frequently than any other responses. For each predicted response, we may ask whether it occurs significantly more frequently than would be expected, given the null hypothesis that subjects choose randomly among permissible responses. With the same one exception as before, the null hypothesis can be rejected with great confidence (in each case, $p < 0.001$ for a one-tail test based on the binomial distribution).

It seems clear that subjects are drawing on each of the three rules of closeness, accession and equality to identify focal points. When two rules conflict, each rule seems to attract some people. Our design does not allow us to test for which rule is the most important in any absolute sense, since which rules people find most salient may depend on the particular distribution of circles and squares in the grid. (For example, the rule of accession seems to have considerable salience in Game 20, but very little in Game 16.)

It is noticeable that significant numbers of subjects are attracted to responses which divide the circles equally between the two squares, but without using the median line rule. For example, in Game 11, 74 per cent of subjects chose LR in line with our prior expectation; but a further 23 per cent chose the other equal assignment, RL. Only 3 per cent of subjects chose unequal assignments (LL or RR). Game 18 provides another example. In this case, none of our three rules of selection implies a unique choice, but 89 per cent of subjects chose one of the two equal assignments while only 11 per cent chose unequal ones. These results provide further evidence of the significance of equality as a shared concept of salience.

Close inspection of Table II reveals a further regularity, which may appear rather curious: it is certainly not one that we had any prior expectation of finding. In seven of the nine games involving two or more circles, the second most common response is a 'mirror image' of the most common response. That is, the two responses differ only in the transposition of 'right' for 'left' and vice versa. For example, in Game 15, 71 per cent of subjects chose LLR, in line with the rule of closeness. The second most common response, chosen by 13 per cent of subjects, was RRL. This latter response would be implied by the rule of assigning each circle to the *more distant* square. Or consider Game 16, in which 68 per cent of subjects chose LLRR, in line with the median line rule. The second most common response, chosen by 15 per cent of subjects, was RRLL. This response would be implied by the rule of finding a median line and then assigning circles on the left of the line to the *right* hand square, and circles on the right of it to the *left* hand square.

After some of the experimental sessions, we invited the subjects to talk about the reasoning they had used in making their choices, and recorded these discussions. They did not find it easy to articulate their reasoning in relation to Games 11–20, but several spoke of having tried to produce a pattern of coloured circles and squares in which the two colours were 'balanced'. For example, one subject said: 'I did it on the grounds of balance: so that if you had one red, I put two blue; and if you had one blue, I put two red with it.' Another said: 'I tried to find a pattern alternating the colours', and spoke of 'trying to balance colours'. If one thinks of symmetry and balance in aesthetic terms, the idea of associating red circles with blue squares and blue circles with red squares has a definite appeal. This kind of reasoning may account for the 'mirror image' assignments.

For two of the games (Games 17 and 18), we made no predictions. These games, we have said, posed subjects with stiff challenges. The responses to Game 18 suggest that most subjects used the rule of equality to narrow down the set of possible responses: 89 per cent chose one of the two equal assignments, while only 11 per cent chose one of the two unequal ones. They were less successful in finding a common criterion to discriminate between L and R in Game 17, or between LR and RL in Game 18, but even here there is some suggestion of a systematic asymmetry in responses. One possible explanation is that subjects made use of the western convention of reading from left to right and from top to bottom, and thus gave 'top' and 'left' some kind of priority over 'bottom' and 'right'.[4]

5. CONCLUSIONS

The results presented in this paper suggest that behaviour in coordination games is indeed sensitive to elements of common knowledge which relate to the labelling of strategies, and which are usually treated as external to any solution concept. This leads us to conclude that the theory of games must embody an account of the role of salience if it is to be satisfactory from a descriptive point of view. Moreover, there seems to be strong support for the hypothesis that the subjects in our experiment drew on the particular rules of selection that we identified – the rules of closeness, accession and equality. This suggests that it is not unrealistic to hope to construct a theory of salience which has predictive power.

The rules of closeness, accession and equality have obvious application to bargaining problems in which a set of valuable objects has to be divided by agreement between two claimants. Our experimental results do not bear *directly* on such problems, since the games we have studied have been ones in which there are no conflicts of interest. Nevertheless, we conjecture that the rules of closeness, accession and equality may play a significant role in determining the outcomes of bargaining games.

In the context of bargaining games, it would be possible to interpret the rules of closeness, accession and equality as principles of *fairness*; if bargainers are observed to act in accordance with such rules, this might be attributed to their having a 'preference for fairness' (e.g. Kahneman, Knetsch and Thaler, 1986). Given that salience often depends on analogy and metaphor, the salience of these rules in our pure coordination games might conceivably arise out of analogies with common ideas of fairness. But an alternative interpretation of our results is possible: the salience of closeness, accession and equality might reflect, not prior notions of fairness, but shared conceptions of symmetry and balance. Indeed, as Hume suggests, the analogies might run the other way: ideas about fairness may derive from more basic notions of salience of the kind that our experiment has revealed.

A final issue needs to be considered: the implications of our results for the development of normative rational choice theory. People apparently act as if following certain rules of salience – as if doing their part in bringing about a salient solution. And, by so doing, they are often able to perform 'better' than standard rational choice theory would predict. But, this said, there remains an open question about whether it is mere good fortune that endows real people with some non-rational propensity to do the salient or, alternatively, whether real people act in this way for well-grounded reasons yet to be properly understood by game theorists. This, we believe, is an issue well worth further consideration.

ACKNOWLEDGEMENTS

This research was supported by the Economic and Social Research Council (award numbers R 000 23 1840 and R 000 23 2269) and by the Economics Research Centre of the University of East Anglia. We are grateful for the comments of an anonymous referee.

NOTES

1 These parallels are examined in more detail by Sugden (1986).

2 The wording of this instruction, and that of Game 6, is unfortunate in that the ordering of the two words in the instruction might suggest the idea of coordinating on the first word. In a later investigation of pure coordination games, we asked subjects to complete the sentences 'A coin was tossed. It came down —s.' and 'The doctor asked for the

patient's records. The nurse gave them to h—.' These instructions yielded results that were very similar to those for Games 3 and 6 in the experiment reported in this paper.

[3] Interestingly, in the discussion sessions that we held with some of the subjects after running the experiment, two subjects explained their choices in Game 7 on the grounds that their chosen cities (Birmingham and Oxford) were in the 'middle' of Britain.

[4] It is hard to articulate exactly why the convention of reading from top to bottom and from left to right suggests the assignment L for Game 17 and LR for Game 18. But, before running the experiment, we (the three authors of the paper) had speculated that subjects might choose these assignments for this reason. Independently, the referee of an earlier draft of this paper (in which no mention was made of this line of thought) came up with the same suggestion.

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School of Economic and Social Studies,
University of East Anglia,
Norwich NR4 7TJ, U.K.