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GROUP CHOICE: THE IDEAL FREE DISTRIBUTION OF HUMAN SOCIAL BEHAVIOR

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Group choice refers to the distribution of group members between two choice alternatives over time. The ideal free distribution (IFD), an optimal foraging model from behavioral ecology, predicts that the ratio of foragers at two resource sites should equal the ratio of obtained resources, a prediction that is formally analogous to the matching law of individual choice, except that group choice is a social phenomenon. Two experiments investigated the usefulness of IFD analyses of human group choice and individual-based explanations that might account for the group-level events. Instead of nonhuman animals foraging at two sites for resources, a group of humans chose blue and red cards to receive points that could earn cash prizes. The groups chose blue and red cards in ratios in positive relation to the ratios of points associated with the cards. When group choice ratios and point ratios were plotted on logarithmic coordinates and fitted with regression lines, the slopes (i.e., sensitivity measures) approached 1.0 but tended to fall short of it (i.e., undermatching), with little bias and little unaccounted for variance. These experiments demonstrate that an IFD analysis of group choice is possible and useful, and suggest that group choice may be explained by the individual members' tendency to optimize reinforcement.

Key words: group choice, ideal free distribution, social behavior, matching law, card choices, humans

Most analyses of social behavior attempt to reduce it to the behavior of individuals (Guerin, 1994; Skinner, 1953). In this paper, we present an analysis of group behavior that may have interesting properties separate from the behavior of individuals. We call the social behavior *group choice* and borrow from behavioral ecology the conceptual and quantitative model of the ideal free distribution (IFD) of foragers to describe group choice (Fretwell & Lucas, 1970; Kennedy & Gray, 1993). The IFD derives from optimal foraging theory, which assumes that animals behave so as to increase evolutionary fitness (e.g., by maximizing net gain in calories); given some constraints, predictions can be made about behavior (for a review of optimal foraging theory, see Stephens & Krebs, 1986). Although research on the IFD has been done primarily with nonhuman animals, the IFD may apply to general human social behavior as well.

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Fretwell and Lucas (1970) originated the IFD in predicting group foraging in birds in relation to resource distribution between habitats. For example, if Habitat 1 were twice as suitable for habitation as Habitat 2 (twice as many food resources, half as many predators, etc.), then twice as many birds should be distributed to Habitat 1 as Habitat 2. If the flock were not distributed ideally (e.g., remained at equal numbers at each territory when twice as many resources were obtainable at one territory compared to the other), then the birds at the lean territory would each gain less than the birds at the richer territory. Some of the birds in the lean territory could better their situation if they switched to the richer site. Fretwell and Lucas's IFD predicts that in general the ratio of foragers at two sites will equal the ratio of resources obtained at the two sites. The equation can be expressed as

$$\frac{N_1}{N_2} = \frac{R_1}{R_2}, \tag{1}$$

where N_1 and N_2 equal the numbers of foragers at two sites and R_1 and R_2 equal the resources obtained at those sites. Equation 1 is structurally equivalent and conceptually analogous to Herrnstein's description of an individual organism's allocation of behavior as a function of the rates of reinforcement associated with the alternatives (i.e., the matching law; Herrnstein, 1961, 1970). The IFD is sometimes called habitat matching because the distribution of foragers is predicted to match the distribution of resource suitability (Pulliam & Caraco, 1984). Fretwell and Lucas based their prediction on four assumptions: All foragers (a) maximize their net resource intake, (b) have perfect knowledge about the obtainable resources, (c) do not differ in competitive ability to obtain resources, and (d) experience reduced resource intake as forager density increases at a resource site. When these assumptions have been approximated, the predictions of the IFD have been confirmed. For example, Harper (1982) distributed food resources (pieces of bread thrown at equal or different rates) at two sites at the edge of a pond and observed the distribution of a flock of ducks. When the distribution of bread at the two sites was equal, the distribution of ducks was equal, and when twice as many pieces of bread were obtainable at one site compared to the other, then twice as many ducks foraged at the richer resource site.

Fretwell and Lucas (1970) described the IFD of foragers as a fluid or dynamic event. If the group of foragers is not distributed ideally for any reason, the group is predicted to readjust toward an IFD. For example, if some of Harper's (1982) ducks at the rich site moved to the lean site, the group would have deviated from the IFD prediction. But, in time, some ducks would be expected to move to the rich site to reestablish the predicted IFD of foragers. The ducks that switch to the rich site might be the ducks that originally disrupted the IFD or they might be other ducks. This example highlights a remarkable quality of Fretwell and Lucas's (1970) model: Aside from its general assumptions, the IFD is silent about the behavior of the individual foragers comprising the group.

Our research with a flock of pigeons supported a dynamic description of the IFD of foragers (Baum & Kraft, 1998). In one experiment, we presented prey items (dried whole peas) at two resource sites (1.2 m square areas separated by 1.2 m) at differing rates to a flock of pigeons. For example, at one resource site single peas were presented at a rate of four per minute (on average), and at the other site peas were presented at a rate of two per minute (on average). Overall, the distribution of pigeons was sensitive to the distribution of resources, although it fell short of the exact matching prediction. During an experimental session, the total number of foragers fluctuated, and many pigeons switched from one site to the other. Nevertheless, despite the fluctuating behavior of the group members, the approximation to the IFD remained constant.

An individual organism's behavior sometimes deviates from perfect matching. To account for these deviations, Baum (1974, 1979) proposed a generalized version of the matching law that took the form

$$\log\left(\frac{B_1}{B_2}\right) = a \log\left(\frac{r_1}{r_2}\right) + \log b, \qquad (2)$$

where B_1 and B_2 represent the behavior allocated to two alternatives, r_1 and r_2 represent the reinforcement obtained from the two alternatives, b is a bias term that denotes a preference for one alternative over the other that is independent of the relative rates of reinforcement, and a (sensitivity) is the parameter that assesses the degree of matching. When sensitivity equals 1.0, then relative responding is proportional to relative reinforcement. If sensitivity is less than 1.0, then the behavior ratio falls short of matching, a result referred to as undermatching, and if sensitivity is greater than 1.0, then the behavior ratio exceeds matching, a result referred to as overmatching.

Ideal free distribution researchers also faced the issue of assessing deviations from IFD matching, and have used a generalized IFD equation that is analogous to Equation 2 (Fagan, 1987; Kennedy & Gray, 1993). The generalized IFD equation takes the form

$$\log\left(\frac{N_1}{N_2}\right) = a \log\left(\frac{R_1}{R_2}\right) + \log b, \qquad (3)$$

where b (bias) refers to a group's preference for a resource site that is independent of the ratio of resources obtained at the sites and a (sensitivity) refers to the degree of matching between the forager ratios and resource ratios. Kennedy and Gray assessed the estimates of sensitivity obtained in previous studies using groups of insects, fish, birds, and whaling ships. Like reviews of research on the matching law (e.g., Baum, 1979), Kennedy and Gray's review of the IFD indicated a consistent tendency for groups of foragers to undermatch obtainable resources. The mean sensitivity (*a*) was .70.

In the one published study of the IFD in groups of humans, Sokolowski, Tonneau, and Freixa i Baque (1999) had groups of 15 adults sit at a table and raise either a green or red card to receive points that could lead to money prizes. The probability of obtaining points varied depending on how many individuals raised a green or red card and how many points were obtainable from raising each card. In each trial, every participant chose a green or red card and placed it on the table for all participants to see. Then participants were permitted to switch cards, and their choices became final when no one had switched for 6 s. Each participant had a set of green and red chips engraved with an identification number, and the experimenter collected a green chip from each participant who chose a green card and a red chip from each participant who chose a red card. The collected green and red chips were placed in separate containers, and the experimenter selected chips from each container randomly to determine which participants received points for that trial. The experimenter manipulated the point distribution ratios by selecting different proportions of chips from each container. For one set of trials, two chips were pulled from the green container and eight from the red (i.e., a 1:4 point ratio). In other sets of trials the ratio of drawn green and red chips varied. The results supported an analogy in which raising differently colored cards was equivalent to foragers residing at resource sites and money was equivalent to primary resources used in IFD experiments. Like the behavior of groups of nonhuman animals, the group behavior of humans was sensitive to distribution of resources (i.e., money), but undermatching was obtained. Sensitivity ranged from 0.62 to 0.70. The procedure used by Sokolowski et al. was the model for the present research.

The present research sought to replicate the IFD in humans, using procedures that were simpler than those of Sokolowski et al. (1999), and to promote inferences about the relation between the group's behavior and the individuals' behavior. Like Sokolowski et al., we had groups of adults sit at a large conference table and raise cards (blue or red) to receive points. The members of the group who earned the most and second-most points won cash prizes. Although our procedure is based on the one used by Sokolowski et al., the mechanism for distributing points was different. During each set of trials, a certain number of points were allocated to each color, and the points allocated to each color were divided evenly among those who chose that color. For example, if 100 points were allocated to all those who chose blue cards, and 5 people chose blue cards, then each participant would receive 20 points. If 20 points were allocated to participants who chose red cards, and 10 participants chose red cards, then each would receive 2 points. The procedure was designed to meet the four assumptions of the IFD. The cash prizes provided incentive for individuals to maximize point intake (i.e., resource intake). Sitting around the table, participants could observe everyone's card choices and earned points, and could acquire perfect knowledge of the resource distribution. The mechanism for distributing points ensured that, as more participants chose a card color, each participant in the card-choice subgroup earned fewer points (i.e., as density of foragers increased, resource intake decreased). Prohibiting talking or any interference with other participants' card choices minimized differences in competitive ability. The procedure might be compared to nonhuman IFD procedures except that the present experiments used humans obtaining points potentially exchangeable for money instead of foragers consuming prey items. However, the present IFD study differed from a free-operant animal study like that of Baum and Kraft (1998) in some important ways. For example, the present study used discrete trials. Participants' choices started from a neutral position (i.e., showing no card) in the present study, but animals in a free-operant study make choices from a spatial position dictated by their last choice. In most IFD research, animals must travel when switching between sites, but no such travel cost existed for the human participants in the present study. In addition, participants in the present study earned secondary reinforcers (i.e., points), whereas subjects in the animal study obtained primary reinforcers (i.e., food). These differences (and others) serve as a context for affirming the generality of the IFD relation if the present studies reveal group choice matching.

EXPERIMENT 1

In Experiment 1, a single group of participants experienced eight blocks of trials across 4 days, in which the ratio of points obtained for choosing blue and red cards remained the same within each trial block but varied between blocks. Group-level outcomes were recorded by the experimenter, and individual-level outcomes were self-recorded by participants. The procedure thus enabled an analysis of group choices (i.e., ratios of blue to red cards) as well as the choices of each individual. An IFD analysis based on Equation 3 was used to evaluate group behavior, and the individual-level events were explored with descriptive statistics (i.e., frequency distributions, phase-space analyses, and correlations). Most of the analyses used in the present study are parallel to the ones used in Baum and Kraft's (1998) research with pigeons. All data analyses used the portions of data that were characterized as steady state, except where noted.

Method

Participants. Thirteen undergraduates (7 women and 6 men) from introductory psychology classes at the University of New Hampshire participated. The participants ranged in age from 18 to 20 years and received partial course credit for their participation in addition to any cash prizes awarded during the experiment. On any of the 4 days of the experiment (two blocks of trials per day), 10 to 12 of the participants arrived on time to participate in the next block of trials. The number of participants varied because a few arrived late or attended only some of the sessions.

Materials. For each block of trials, each participant received both blue and red index cards (10 cm by 18 cm), a pen, and a score sheet. The score sheet consisted of a table of 40 rows, and each row had space for the participant to mark the card color chosen and points received for each trial in the block. The experimenter had a table that described point distributions and a score sheet to record the number of participants who raised red and blue cards at the end of each trial. The participants sat at a large conference table with the experimenter at the head of the table.

Procedure. On the 1st day, participants signed an informed consent agreement and received an introduction to the procedure. Although the scripted instructions were lost after the investigation was completed, they were minimal; thus, most aspects are readily paraphrased. The experimenter instructed the participants that they were going to play a game. To begin a turn in the game, they were instructed to hold a card in each hand under the table at the beginning of each trial. The experimenter then said, "Please raise one card now," and each participant quickly placed either a blue or red card on top of the table in such a way that the others could see it. The experimenter recorded the number of participants who raised blue and red cards ("before-switch" data) and instructed all the participants that they could switch cards. The experimenter waited until 5 s had elapsed since the last person switched cards before saying that no more switching was allowed. The experimenter recorded the number of participants who raised blue and red cards ("after-switch" data) and announced the points earned. During the introduction to the experiment, the participants were told that during each block of trials, a certain number of points was allocated to the subgroup who raised blue cards and to the subgroup who raised red cards, and that each member of the card subgroup shared the allocated points. The number of points given to a participant at the end of each trial was equal to the number of points allocated to the participant's card subgroup divided by the number of participants who raised that color. The participants were given the example of 5 people raising a particular card color that was allocated 60 points with the result that each would receive 12 points. The participants were told that the number of points allocated to blue and red cards did not change during a block of trials, but would change from block to block. They were not told the number of points allocated to each card during any block of trials. The experimenter instructed the participants that they must record the color card chosen and the points they were awarded on their score sheet at the end of each trial. They were told that dishonest reporting of earned points would lead to disqualification for the prizes. Finally, the participants were instructed that the person who earned the most points at the end of the experiment would be mailed a \$35 cash prize and that the second-place winner would be mailed \$5. Participants were given the opportunity to ask questions before beginning the experiment. Most answers required the restatement of the instructions.

Eight blocks of 40 trials were held during 1 week (two blocks of trials per day) except that on Day 1 late-arriving participants caused the first two blocks of trials to be shortened to 35 to fit the available time. The points allocated to blue and red cards were distributed in 100:20, 80:40, 40:80, or 20:100 ratios. The point allocation did not change during a block of trials but varied from block to block in the following pattern: 1:5, 2:1, 5:1, 1:2, 1:2, 5:1, 2:1, and 1:5. At the end of each block of trials, participants turned in their score sheets, and points were tallied at the end of the experiment. To promote participation, the experimenter began each day by noting that the differences among participants in accumulated points were small and that anyone could still win the larger cash prize (a truthful statement). Several weeks after the experiment was concluded, checks for \$35 and \$5 were mailed to the participants who earned the most and second-most points.

Participants' self-recorded data. The participants' self-recorded data were used for the individual-level analyses. At the end of each trial, participants recorded their after-switch choices and the number of points earned. Relying on participants to record their own data introduces the possibility of recording errors. We anticipated that participants might have been tempted to misreport choosing membership in the rich group. We warned them not to do so and alerted them that we would check. Although the experimenter had no way to know which participant misreported choices and points, any systematic misreporting would be evident from a comparison of the experimenter-recorded distributions of participants and points allocated with the collective self-records of the individuals.

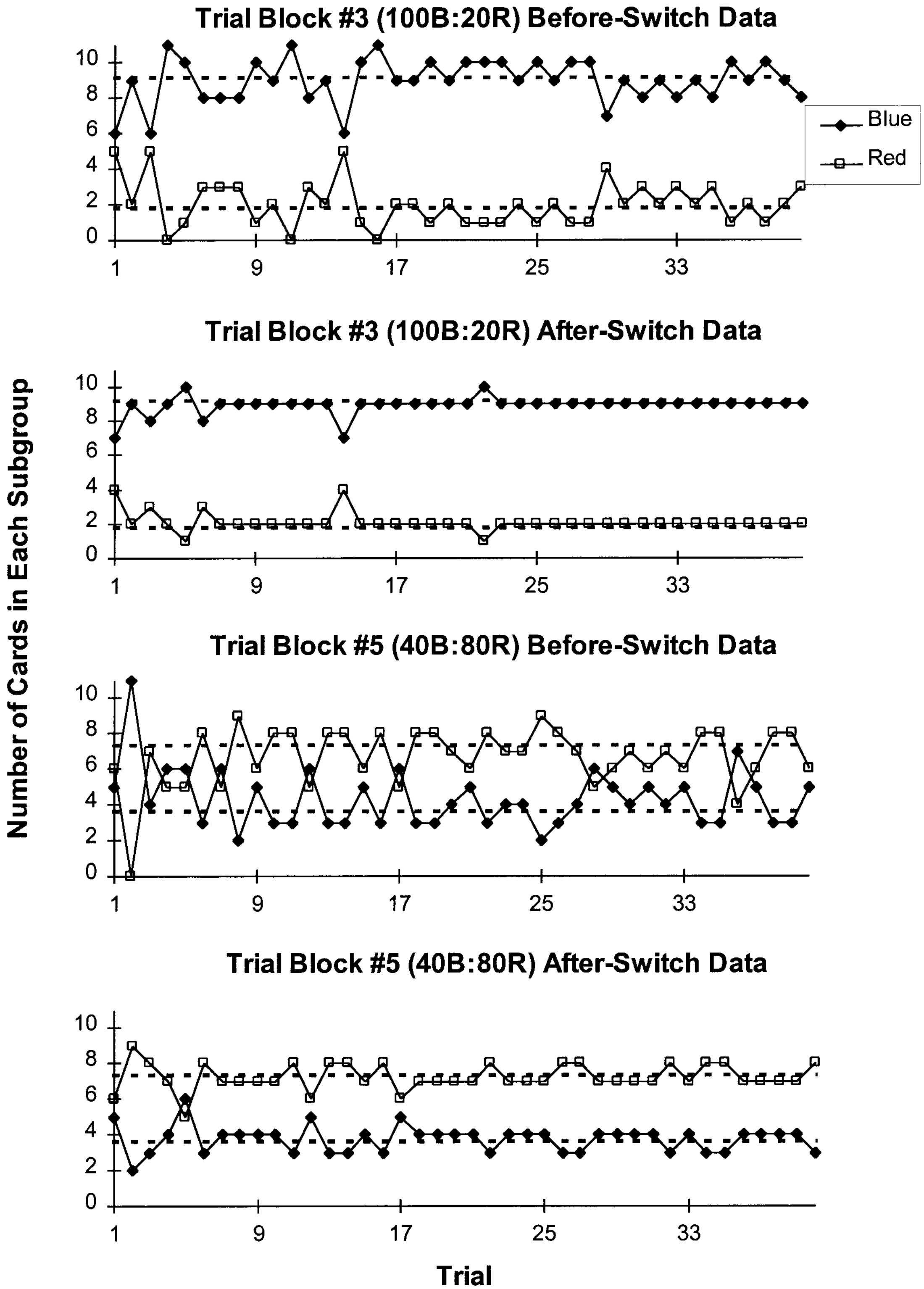
Results

Group-level analysis. The group-level data were collected by the experimenter and consisted of the numbers of participants who chose to be in subgroups, but not the identity of subgroup members.

Two examples of typical blocks of trials are depicted in Figure 1. The top two panels show the before- and after-switch trial-by-trial numbers of blue and red card choices for Trial Block 3, in which points were distributed in a 100:20 ratio. The bottom two panels show the before- and after-switch numbers of blue and red choices for Trial Block 5, in which points were distributed in a 40:80 ratio. The dashed lines in each panel indicate an ideal card-choice distribution for each trial. With 11 people participating in the example trial block, the 5:1 point ratio (top panels) yielded a predicted card-choice ratio of 9.17 participants choosing blue cards and 1.83 choosing red cards. The 1:2 point ratio trial block (bottom panels) yielded a predicted card-choice ratio of 3.67 to 7.34. In neither block could the group distribute perfectly on any one trial, and the dashed lines indicate the group's non-whole-number approximations to the ideal distribution. Three characteristics of the trial-by-trial data are evident. First, the group's card choices approximated IFD predictions. Second, the before-switch data were more variable than the after-switch data. Third, visual inspection suggests that stable group patterns emerged after five or six trials.

To determine the degree of matching between group choices and point distribution, the ratios of blue and red choices were plotted against their respective blue and red point ratios in double logarithmic coordinates. To construct the blue:red choice ratios, the average number of blue choices during each trial block (excluding the first six trials) was divided by the average of the red choices (excluding the first six trials).

The upper panel of Figure 2 depicts participants' before-switch choices. Qualitatively, most of the data points fell close to the major diagonal that indicated perfect matching and no bias. Quantitatively, the linear regression indicated that a line with y intercept of 1.05 (i.e., bias) and slope (i.e., sensitivity) of 0.84 produced the least squares fit (r^2 = .9937).


Trial Block #3 (100B:20R) Before-Switch Data
Blue
Red
Trial Block #3 (100B:20R) After-Switch Data
Trial Block #5 (40B:80R) Before-Switch Data
Trial Block #5 (40B:80R) After-Switch Data
Number of Cards in Each Subgroup
Trial
0
2
4
6
8
10
1
9
17
25
33

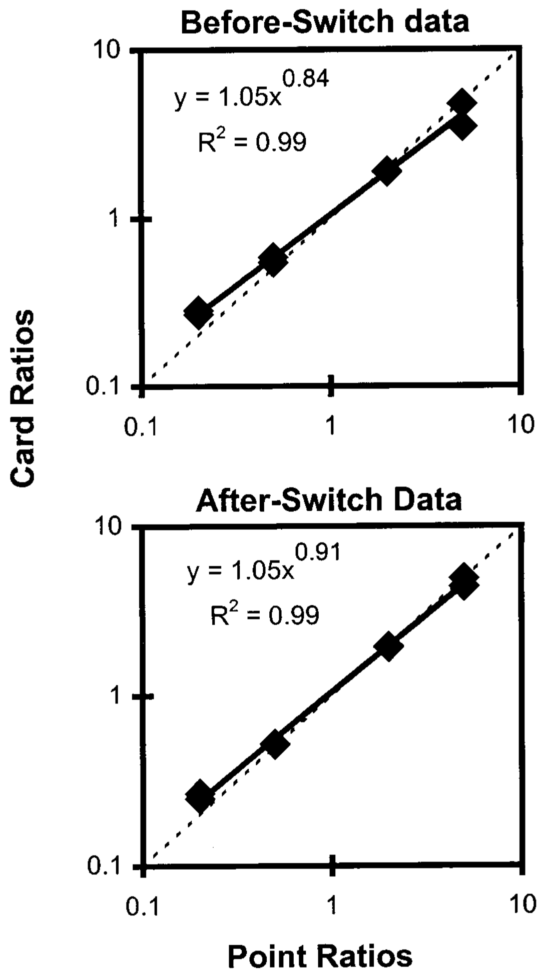


Fig. 2. Choice relations in logarithmic coordinates for Experiment 1. The ratio of the average number of blue to red card choices is plotted against the ratio of blue to red points allocated. Broken lines show the locus of perfect matching. Solid lines were fitted by the method of least squares. The equation of the regression line appears in each graph in power-function form.

The lower panel of Figure 2 depicts participants' after-switch choices. Again, most of the data points fell close to the major diagonal. A line with a y intercept of 1.05 and a slope of 0.91 produced an excellent fit to the data (r^2 = .9972).

In several blocks of trials (e.g., Figure 1), it was impossible for the group to distribute perfectly on any single trial because the group could divide only into whole-number solutions. Table 1 summarizes the number of individuals participating in each block of trials, the number of points allocated to blue and red subgroups, the predicted IFD of the subgroups' choices based on the number of participants and shared points, the observed choices across the trial blocks, and the percentage of trials in which the subgroups matched the point ratio (a = 1), fell short (i.e., undermatched) by 1 individual (a < 1 because of 1 excess person in the lean-alternative group), and exceeded the point ratio (i.e., overmatched) by 1 individual (a > 1 because of 1 excess person in the rich-alternative group). In addition, Table 1 includes the points earned by individuals for choosing blue and red cards when the groups undermatched and overmatched by 1 individual. In six of the eight trial blocks (Blocks 1, 2, 3, 4, 5, and 7), the number of individuals who participated and the points shared among subgroup members predicted a non-whole-number IFD solution. Although this distribution was impossible on any single trial, a mixture of overmatching and undermatching within a block could produce it on average. The observed group distribution across blocks showed that the group did not meet the predicted IFD solution but, instead, undermatched. When a perfect IFD was impossible in single trials, the groups undermatched by 1 individual in a majority of trials. The predominance of undermatching may reflect the greater disparity in points between subgroups when they overmatched. For example, in the first trial block, individuals in the blue and red subgroups earned 10 and 12.5 points, respectively, when they undermatched (a disparity of 2.5 points), whereas they earned 20

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Fig. 1. Two sample sessions of before- and after-switch data from Experiment 1. The top two panels show a session in which all the participants who raised blue cards shared 100 points and all the participants who raised red cards shared 20 points. The bottom two panels show a session in which 40 points were allocated to blue cards and 80 points to red cards. For both sessions, participants' initial choices at the beginning of the trials (before-switch numbers) and final choices after switching had occurred (after-switch numbers) are shown. Heavy horizontal lines indicate the predictions of the IFD.

Table 1

Summary of Experiment 1 trial blocks.

						$a < 1$ by 1		$a = 1$		$a > 1$ by 1	
Trial block	n	Card color	Shared points	Predicted number	Observed number	% of trials	Earned points	% of trials	Earned points	% of trials	Earned points
1	10	Blue	20	1.67	2.10	68	10			10	20
		Red	100	8.33	7.90		12.5				11.1
2	11	Blue	80	7.33	7.24	58	11.4			29	10
		Red	40	3.67	3.76		10				13.3
3	11	Blue	100	9.17	8.97	94	11.1			3	10
		Red	20	1.83	2.03		10				20
4	11	Blue	40	3.67	3.76	65	10			24	13.3
		Red	80	7.33	7.24		11.4				10
5	11	Blue	40	3.67	3.74	62	10			32	13.3
		Red	80	7.33	7.26		11.4				10
6	12	Blue	100	10	9.97	3	11.1	93	10	0	9.1
		Red	20	2	2.03		6.7		10		20
7	11	Blue	80	7.33	7.35	76	11.4			24	10
		Red	40	3.67	3.76		10				13.3
8	12	Blue	20	2	2.38	38	6.7	58	10	0	9.1
		Red	100	10	9.62		11.1		10		20

Note. The first six trials were excluded in calculating observed participant numbers and percentages of trials in which the group undermatched by 1, overmatched by 1, or matched.

and 11.1 points, respectively, when they overmatched (a disparity of 8.9 points). By undermatching a majority of the time, individuals tended to minimize the disparity in earned points. In the two trial blocks in which a perfect IFD solution was possible, the group mostly matched, equalizing the individuals' point gains.

Individual-level analysis. Analyses of individual choices were based on data self-recorded by the individual participants. To check for any systematic misreporting, the experimenter's records of blue and red choices were compared with the aggregated records of the individuals. We compared the experimenter's counts with individual participants' collective accounts in all trials except the first six of each block (i.e., those trials not used in the group-level analysis). Of these 262 comparisons, the experimenter's counts and the participants' collective accounts differed in only seven trials (2.7%). In five trials (1.9%), the experimenter recorded a more extreme distribution than suggested by the individual records, and in two trials (0.8%), the converse was true. However, nonsystematic misreporting could not be detected because of the way we collected the data. For example, when 5 people chose blue and 5 people chose red (and the experimenter recorded the same distribution), all or some portion of the participants could have misrecorded choices and points in such a way as to exactly cancel one another out. If this were to happen, the experimenter's records and individuals' self-records would correspond, but nonsystematic error would exist in the individuals' self-recorded data.

The IFD depends on the assumption that individuals maximize their net resource intake. If all individuals maximized net gain, all the individuals should have gained the same number of points. Figure 3 presents histograms of the number of points individuals earned on every trial (excluding the first six) for each trial block. The numbers on the x axis represent the upper limit of the bin (e.g., earning 10 points fell in the 10-point bin and earning 12.5 points fell in the 13-point bin). In every trial block, the majority of individuals earned 10 to 13 points. Figure 3 indicates that individuals were maximizing net resource gain, just as the optimization assumption of the IFD required and as one might expect if group matching occurred.

To determine the orderliness of individuals' preferences, a preference index was constructed for each individual for each trial block. It consisted of the proportion of trials on which the higher point (rich) card was chosen, minus .5. Preference ranged from −.5 (exclusive preference for the lower point,

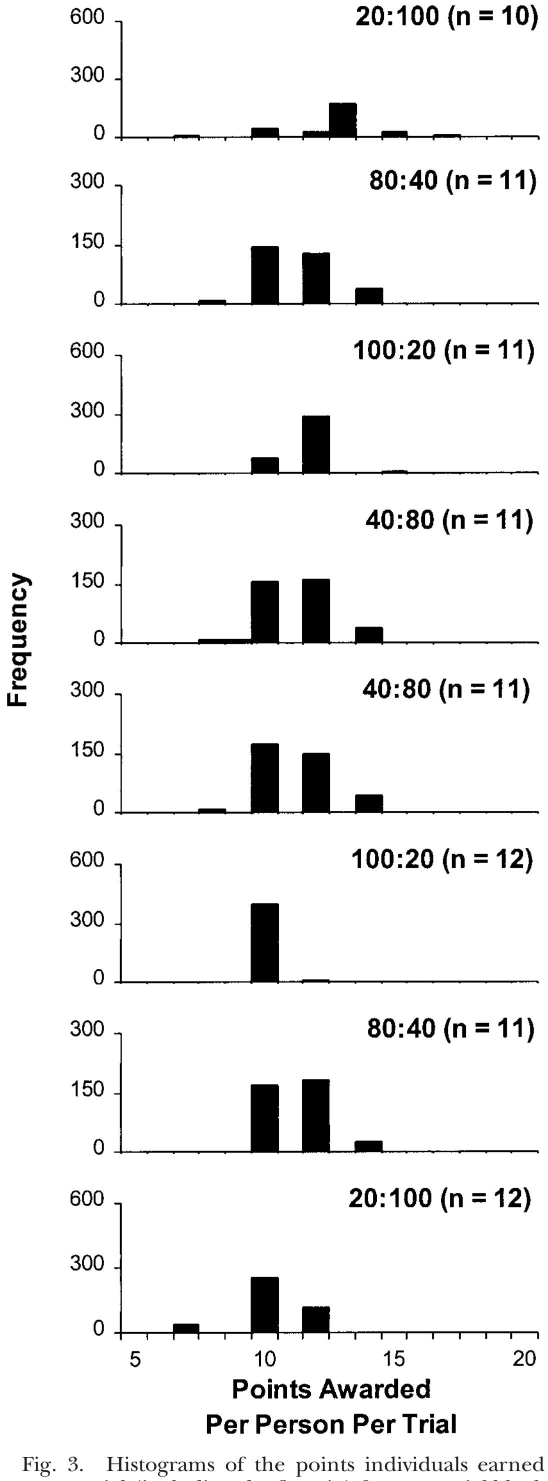


Fig. 3. Histograms of the points individuals earned on every trial (including the first six) for every trial block of Experiment 1. The numbers on the *x* axis represent the upper limit of the bin (e.g., earning 10 points fell in the 10-point bin and earning 12.5 points fell in the 13-point bin). For each trial block, the number of participants and the point ratio are indicated.

lean card) to .5 (exclusive preference for the rich card). A preference of zero indicated that a person chose the rich card as many times as the lean card within a particular trial block. Ratios of 5:1 and 2:1 correspond to preference indexes of .33 and .17. Figure 4 shows histograms of individual preferences for 5:1 and 2:1 rich-card:lean-card ratios. For the 5:1 point ratios, the distribution of individual preferences ranged widely, but a high proportion of individuals (25 of 45) strongly preferred (preference index of .41 to .50) the richer card. The average of the preferences equaled .31. For the 2:1 point ratios, a similar, but less pronounced, pattern of preference emerged. The modal preference for the 2:1 point ratio (20 of 44 individual preferences) was greater than .31, and preference indexes ranged widely. The average preference was .16.

This analysis shows that most individuals did not distribute their choices for cards in ratios equal to the point ratios. However, even though preference indexes varied between individuals, they might have been consistent within individuals. For example, a participant might have recorded similar preferences for the first and second 2:1 trial blocks. To examine consistency, preference indexes were plotted in a phase-space diagram (Figure 5). The phase-space diagram related each individual's preference from Trial Block 1 to Trial Block 2, from Trial Block 2 to Trial Block 3, and so on. This type of phase-space diagram is also known as an autocorrelation with a lag of 1. Consistency would be indicated by a positive correlation.

Fitting a regression line revealed that there was a small to moderate correlation between individuals' preferences in trial block i and trial block $i + 1$, $r(70) = .26$, $p < .05$, with a small amount of variance accounted for ($r^2 = .07$). The lower panel of Figure 5 shows a phase-space analysis of the number of points earned by individuals during trial blocks. Individual point gain ranged from 297.1 to 387.5 across all trial blocks. No significant relation existed between point gain during trial block i and trial block $i + 1$, $r(70) = -.15$, $p > .05$). To further explore the possibility of order on the individual level, preference and points gained during each trial block were related to one another. An individual's preference and points gained during a trial block

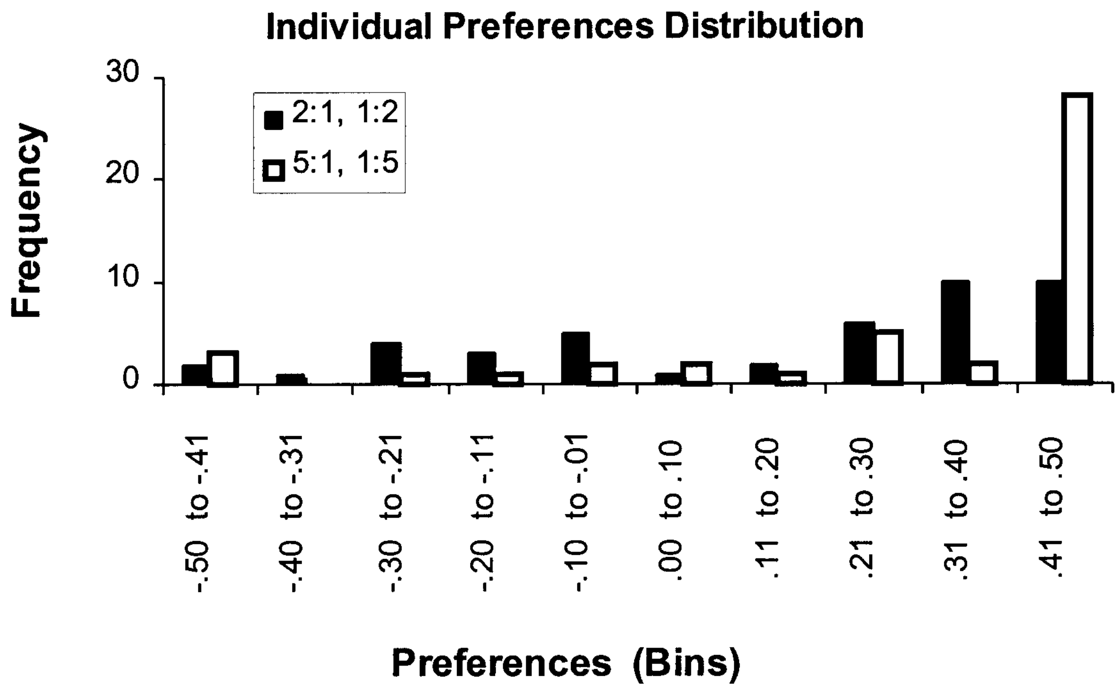
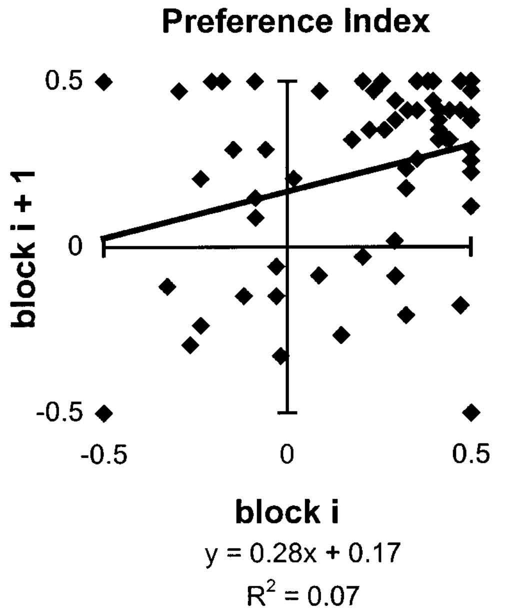


Fig. 4. Frequency distributions of individual preference indexes in Experiment 1. An index of −.5 indicates exclusive preference for the card allocated fewer points, and an index of .5 indicates exclusive preference for the card allocated more points.

were correlated to a small degree, $r(88) = .28$, $p < .05$.

Figure 5 examined consistency across trial blocks. One may also examine consistency within trial blocks, using the lagged correlation of participants' choices from trial to trial. Individuals' choices were coded as 1 for blue and 2 for red. An individual's trial was paired with the next trial, except for the last trial of a block and the first trial of the next block. An individual who chose the same card on every trial would produce a perfect positive correlation, and an individual who alternated on every trial would produce a perfect negative correlation. The average correlation of choices was moderate to strong ($r_{avg} = .58$) where the low correlation was .12 and the highest was 1.0.

Once the group achieved the IFD or its closest possible approximation, switching might be expected to cease. A switch from one subgroup to the other would lead the switcher to receive fewer points (as would all the participants in the group switched into), and all of the other participants in the switcher's previous subgroup would receive more points (all other things being the same). By comparing the number of individuals in each subgroup from trial to trial, one can determine the minimum amount of switching that occurred. For example, if on one trial 11 participants distributed in a 4:7 blue:red ratio and on the next trial distributed in a 2:9 blue:red ratio, then at least 2 participants switched from the blue subgroup to the red. More might have switched, but that could not be determined from the group-level data. For example, all 4 participants in the blue subgroup might have switched into the red subgroup, and then 2 might have switched from the red subgroup to the blue subgroup to maintain the 2:9 blue:red ratio. Because group-level switching might greatly underestimate the amount of actual switching, we estimated frequency of switching by counting the number of individuals whose after-switch choice in a trial differed from their after-switch choice on the previous trial. Of course, such a measure was still conservative in the sense that it relied on comparing after-switch choices only; that is, if an individual chose a different card color at the beginning of the



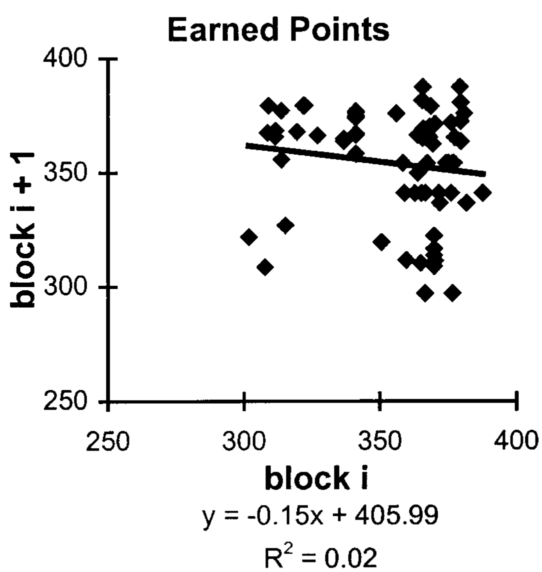


Fig. 5. Phase-space plots of individuals' preferences (top) and points earned (bottom) from session to session (trial block to trial block) in Experiment 1. A high degree of consistency across individuals would appear as a positive correlation. Regression lines, fitted by the method of least squares, are shown, along with their equations and goodness of fit.

next trial, he or she could switch back during the switching period, and no switch would be counted because the after-switch choices would have been the same. Our aim, however, was to discover whether switching was at all frequent. We ascertained this by comparing the individual switch count with the group-level count. It should be noted that differences between individual switch counts and group-level counts were in no sense errors, but rather just allowed us to estimate frequency. Although this method was conservative, it showed that the individuals often switched after an IFD was achieved. Of the 262 comparisons that could be made, the individual measure of switching equaled the group-level switching in only 101 comparisons (38.5%). The individual measure exceeded the group level by two switches in 113 comparisons (43.1%), by four switches in 29 comparisons (11.1%), and by six switches in nine comparisons (3.4%). Ten cases were excluded because of unclear individual records. Thus, in a majority of trials, the individuals apparently switched more than group-level records indicated, suggested that switching was indeed frequent.

Discussion

The group-level analysis supported the predictions of the IFD. Individuals apparently tended to optimize, because the groups achieved point distributions as close to equality as the number of participants allowed (Figure 3). As a result, when the blue card was associated with 100 points and the red card with 20 points, the group's choices of the cards approximated a 5:1 point distribution. For the after-switch data, sensitivity was close to the value of 1.0 predicted (a = .91). Even the before-switch data indicated that the group's initial choices were sensitive to point distribution (a = .84). The group's initial choices may have been determined by the group's choices in previous trials within a block. The small degree of undermatching was probably caused by the impossibility of a perfect IFD due to the number of individuals participating in some trial blocks. For those blocks, the distribution that minimized the discrepancy in individually earned points necessarily fell short of matching.

The variance in individual preferences (Figure 4) revealed that the group-level distribution was not reducible to collective individual distributions. The simplest explanation of group-level matching would have been that each individual matched. For example, when the group distributed in a 5:1 ratio, that could have meant each individual distributed in a 5:1 ratio. Figure 4 indicates that no such uniformity occurred, and neither did the modal individual preference equal the group's preference in either 2:1 or 5:1 conditions.

Although the individual preferences varied, the phase-space analyses of trial-block-by-trial-block individual preference revealed some consistency (Figure 5, top graph). There was no consistency from trial block to trial block on accumulated points (Figure 5, bottom graph), but there was some positive relation between individuals' preferences and the points they earned. The analysis of the individuals' switching suggested that more switching from card color to card color occurred than the group-level data suggested. When the number of individuals in the subgroups stayed the same or changed by 1 or 2, the final distribution often arose from a greater number of switches (i.e., greater than zero, one, or two), some of which canceled each other out.

EXPERIMENT 2

In Experiment 1, point distributions were manipulated across blocks of trials completed on different days. This approach offered the advantage of clearly distinguishing one condition from another, but also had several practical disadvantages. For example, although they were prohibited from talking during each visit to the laboratory, participants might have discussed point-earning strategies with one another between visits. In addition, participants did not always return to the laboratory as scheduled, thereby introducing variability in the number of participants in each block of trials. In Experiment 2, the entire procedure was completed in one visit. To allow several point ratios to be evaluated in one session, the point-ratio conditions lasted for 20 trials, instead of 40 as in Experiment 1. This approach seemed justified because stable patterns of group choice emerged in Experiment 1 after only a few trials.

Experiment 2 was inspired, in part, by Belke and Heyman (1994), who successfully studied choice in individual rats by presenting successive periods of different concurrent schedules during one session. Further encouragement for an abbreviated design came from Bell (1998),[1] who found that an analogous technique was useful in the study of group choice by foraging pigeons.

In Experiment 2, two separate groups of participants completed one long session during which the ratio of points obtained for choosing blue and red cards changed five times. The ratio of points remained constant within a block of trials and changed across blocks of trials. As in Experiment 1, this procedure enabled the analysis of group choices (the proportion of participants who chose blue and red cards) as well as the choices of individuals. The procedure ensured that the same individuals participated in all point-ratio conditions and prevented participants from interacting between conditions.

Method

Participants. Two separate groups of volunteers participated. Group A consisted of 10 undergraduates (5 men and 5 women) and Group B consisted of 16 undergraduates (8 men and 8 women). Participants' ages ranged from 18 to 21 years. All were enrolled in the Introduction to Psychology course at the University of New Hampshire. All received partial course credit for their participation, and some won cash prizes.

Materials. The materials were identical to those used in Experiment 1 except that the score sheets differed. The score sheets included five pairs of columns of 20 rows to indicate the card chosen and earned points on each trial, one column per block.

Procedure. The procedure was similar to that of Experiment 1 except that each group of participants came to a 2-hr session. The session consisted of five blocks of 20 trials. A new blue:red point ratio began with each new trial block. The point ratios occurred in the following order: 40:80, 20:100, 80:40, 100:20, and 40:80. The first block of trials was considered a practice block and was repeated at the end to assess any effects of practice. The participants self-recorded in the same manner as in Experiment 1. Because each block was cor-

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[1] Bell, K. E. (1998). *Group foraging sensitivity to predictable and unpredictable changes in food distribution: Past experience or present circumstances.* Unpublished master's thesis, University of New Hampshire, Durham.

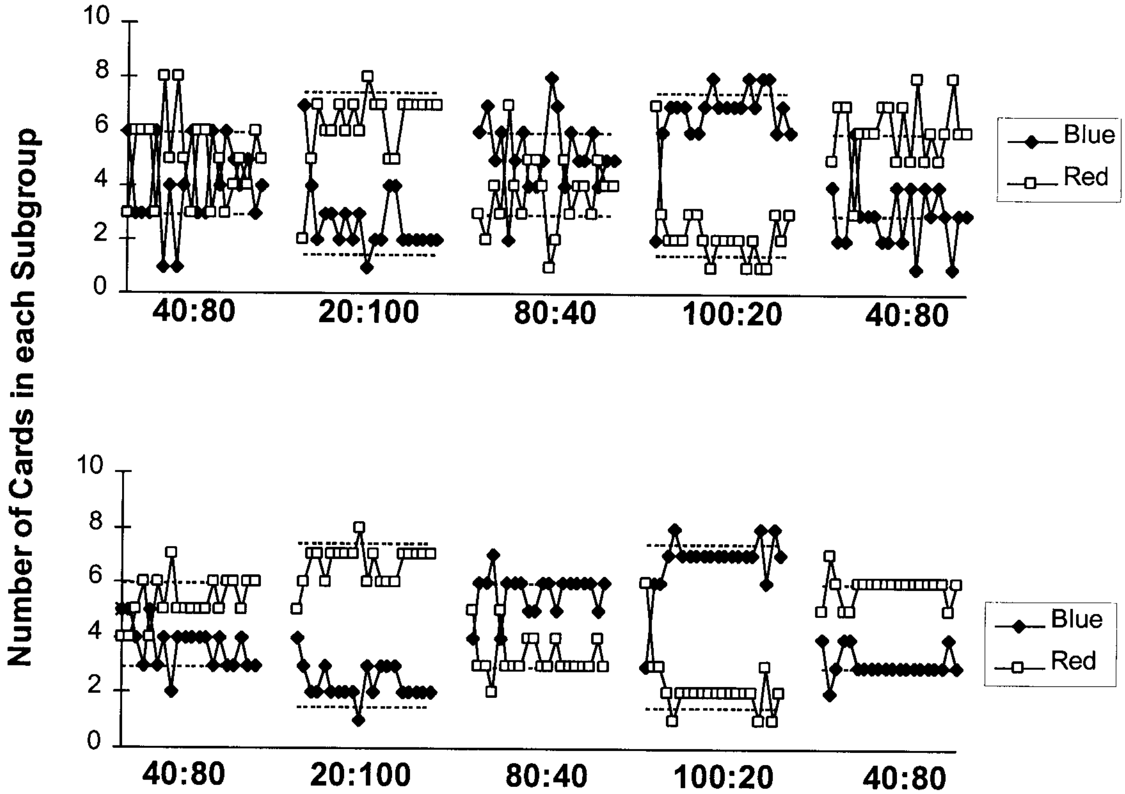


Fig. 6. An example of Experiment 2 data. Group A's trial-by-trial before-switching and after-switching numbers are shown for the entire session, during which the points allocated to blue and red cards changed from block to block of trials in the following order: 40:80, 20:100, 80:40, 100:20, 40:80. Heavy dashed horizontal lines indicate the predictions of the IFD.

related with a new column on the participants' record sheets, after one or two blocks, participants probably recognized that when they finished a column of trials a new point ratio was going to begin. The experimenter said nothing about the point ratios.

Results

Group-level analysis. One sample session is depicted in Figure 6. The graphs show the before-switch and the after-switch data for each of the five blocks of 20 trials for Group A. The horizontal lines depict the predicted blue and red choices based on the 9 participants' distributing in 5:1, 2:1, 1:2, and 1:5 ratios. As in the previous experiment, the before-switch data are more variable than the after-switch data. The first 1:2 block was more variable than the second at the end of the session, for both before- and after-switch data. In each block, the first five or six trials indicated an adjustment period to the new point ratio.

To determine the degree of matching between group choices and point distribution, the choice ratios were compared to the point ratios, as in Experiment 1. To construct the choice ratios, the average of the last 14 trials of blue card choices was divided by the average of the last 14 trials of red card choices for each block of trials (excluding the first block). Figure 7 shows the results. Each panel includes the equation, in power-function form, of the fitted line and the variance accounted for. The dashed major diagonal indicates perfect matching and no bias. For both groups, before and after switching, some undermatching occurred. The two groups' sensitivities (a) differed more before switching (.74 vs. .92) than after switching (.77 vs. .80). Goodness of fit (r^2) was good (.96 or higher). No systematic bias occurred.

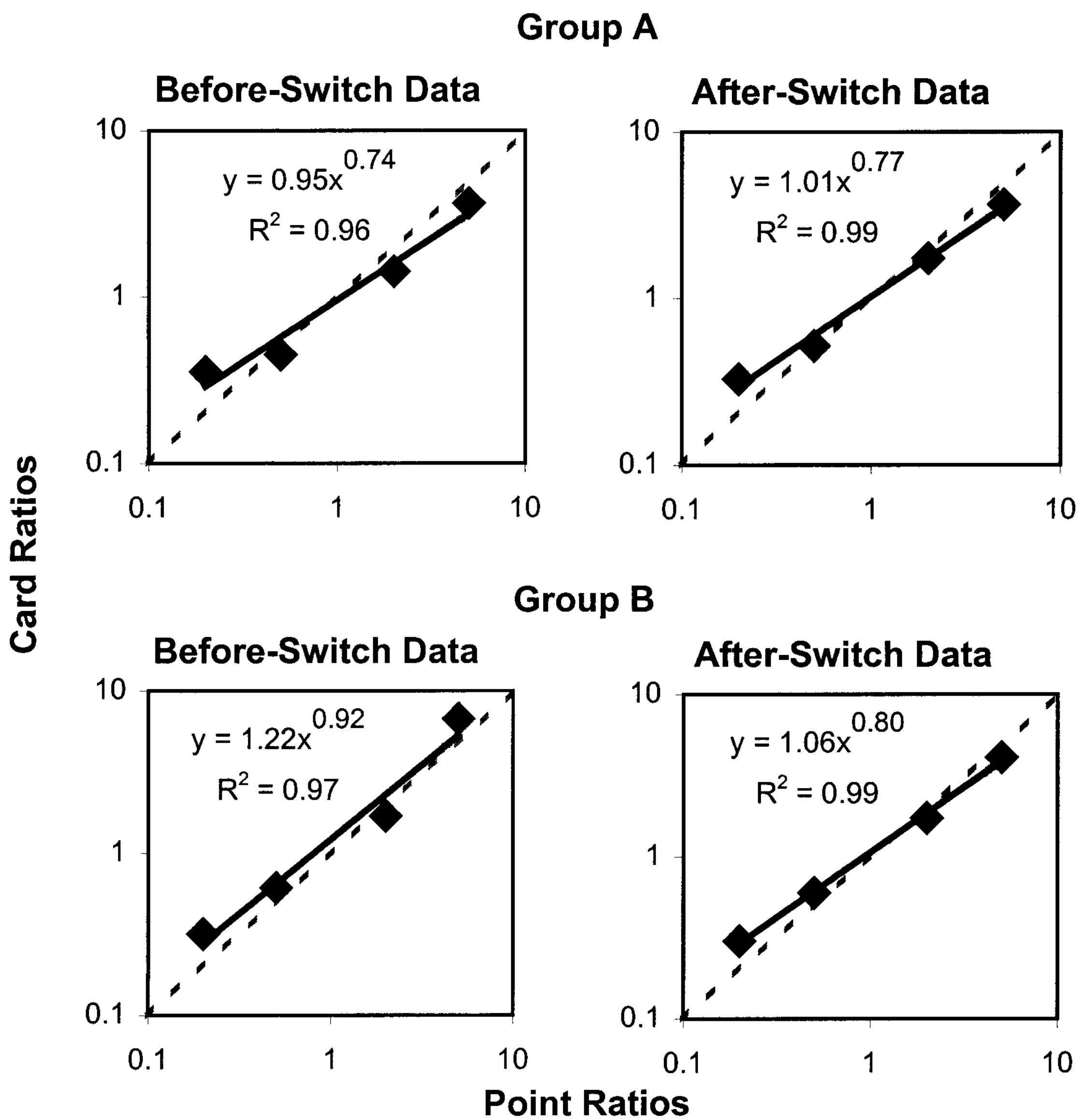


Fig. 7. Choice relations in logarithmic coordinates for Groups A and B in Experiment 2. The ratio of the average number of blue to red card choices is plotted against the ratio of blue to red points allocated. Broken lines show the locus of perfect matching. Solid lines were fitted by the method of least squares. The equation of the regression line appears in each graph in power-function form.

When the two groups' data were pooled (not shown), the results remained orderly for the before-switch data (a = .83, b = 1.08, r^2 = .94) and the after-switch data (a = .79, b = 1.04, r^2 = .99).

In three of the five trial blocks for Group A and all five blocks for Group B, perfect (i.e., whole-number) solutions to the IFD were impossible because of the number of participants. Table 2 presents the number of individuals participating in each block of trials, the points allocated to blue and red subgroups, the predicted IFD of the groups' choices based on the number of participants and shared points, the observed IFD of groups' choices across the block of trials except for the first six trials, and the percentage of trials in which the groups matched the

Table 2

Summary of Experiment 2 (Groups A and B) trial blocks.

						$a < 1$ by 1		$a = 1$		$a > 1$ by 1	
Trial block	n	Card color	Shared points	Predicted number	Observed number	% of trials	Earned points	% of trials	Earned points	% of trials	Earned points
Group A											
1	9	Blue	40	3	3.5	57	10	36	13.3	7	20
		Red	80	6	5.5		16		13.3		11.4
2	9	Blue	20	1.5	2.21	64	10			7	20
		Red	100	7.5	6.79		14.3				12.5
3	9	Blue	80	6	5.71	29	16	71	13.3	0	11.4
		Red	40	3	3.29		10		13.3		20
4	9	Blue	100	7.5	7.07	79	14.3			14	12.5
		Red	20	1.5	1.93		10				20
5	9	Blue	40	3	3.07	7	10	93	13.3	0	20
		Red	80	6	5.93		16		13.3		11.4
Group B											
1	16	Blue	40	5.33	6.36	29	6.7			14	8
		Red	80	10.67	9.64		8				7.3
2	16	Blue	20	2.67	3.79	43	6.7			7	10
		Red	100	13.33	12.2		7.7				7.1
3	16	Blue	80	10.67	9.93	21	8			36	7.3
		Red	40	5.33	6.07		6.7				8
4	16	Blue	100	13.33	12.71	43	7.7			29	7.1
		Red	20	2.67	3.29		6.7				10
5	16	Blue	40	5.33	5.50	57	6.7			29	8
		Red	80	10.67	10.50		8				7.3

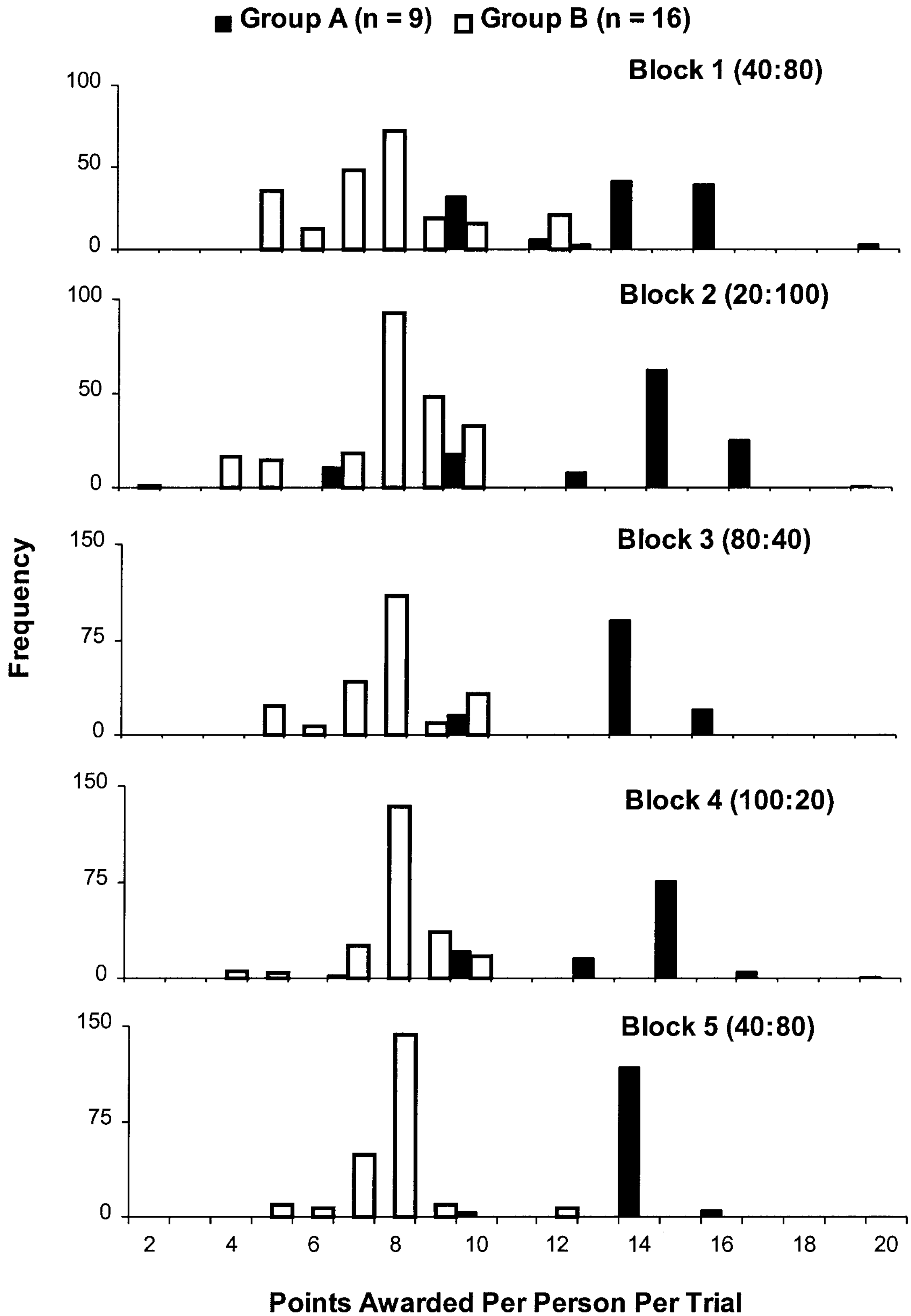
Note. The first six trials were excluded in calculating observed participant numbers and percentages of trials in which the group undermatched by 1, overmatched by 1, or matched.

point ratio, undermatched ($a < 1$) by 1 individual, and overmatched ($a > 1$) by 1 individual. In addition, Table 2 includes the points individuals earned for choosing blue and red cards when the groups undermatched and overmatched the point ratio.

In two of the three blocks in which Group A could distribute perfectly, they did so in a majority of trials, the exceptional trial block being the first and least stable. In the remaining two blocks a perfect IFD solution was impossible and the group undermatched by 1 in most trials, thereby minimizing the difference in points allocated to members of the blue and red subgroups. For Group B, which was also faced with the impossibility of a perfect solution, minimizing the point difference required overmatching by 1 in three trial blocks (Blocks 1, 3, and 5) and undermatching by 1 in the other two trial blocks (Blocks 2 and 4). When undermatching minimized the difference in earned points, Group B generally undermatched. When overmatching minimized the difference, Group B overmatched in a majority of trials in only one of the three trial blocks.

Individual-level analysis. To determine whether there was any systematic error in individuals' self-records of blue and red choices, the experimenter's records were compared with records of the individuals. Of the 56 trials used in the group-level analyses (i.e., last 14 trials of the last four blocks) of both groups, the experimenter's count and the individuals' collective counts differed by one in one trial for Group A and two trials for Group B. With Group A, the experimenter recorded a less extreme distribution than the individuals did in one trial. With Group B, the experimenter recorded a more extreme distribution than the individuals did in two trials. As in the previous experiment, additional nonsystematic errors could have occurred but canceled each other out, thereby remaining undetected in the present analysis.

Figure 8 shows the points individuals earned on every trial (excluding the first six), one histogram for each trial block. Because 9 and 16 individuals participated in Groups A and B and they shared the same numbers of points, the two distributions are offset from one another. The peaks of the Group A his-



■ Group A (n = 9) □ Group B (n = 16)
Block 1 (40:80)
Block 2 (20:100)
Block 3 (80:40)
Block 4 (100:20)
Block 5 (40:80)
Frequency
0
50
100
75
150
2
4
6
8
10
12
14
16
18
20
Points Awarded Per Person Per Trial

tograms indicate that participants usually earned about 14 or 15 points per trial. The peaks for Group B indicate that the participants usually earned about 8 points per trial. The strong modes indicate that individuals tended to distribute in such a way (i.e., ideally) that they all earned approximately the same number of points on most trials.

Figure 9 shows preference indexes calculated for each individual in each block of trials used in the group-level analysis, as was done for Experiment 1 (Figure 4). Preference ranged from −.5 (complete preference for the lean card) to .5 (complete preference for the rich card) for both Groups A and B. Both distributions were bimodal, with the stronger mode at preference for the rich card. The difference between modes was greater for the 5:1 and 1:5 conditions. Although the ideal average preference index was .33 when the rich:lean ratio was 5:1, Group A's average preference index was .29 and Group B's average index was .27. When the rich:lean ratio was 2:1, Group A's distribution remained near .5, whereas Group B's distribution was approximately flat across the range from 0 to .5. When the rich:lean point ratio was 2:1, the predicted ideal preference index was .17. Group A's average preference index was .14, and Group B's average preference index was .13.

Although preference varied across individuals, it was still possible that individual preferences were consistent across blocks of trials. Figure 10 shows preference and points per block plotted in phase-space diagrams for Groups A and B. The phase-space analysis for Group A revealed a strong correlation in preference from block i to block $i + 1$, $r(25) = .64$, $p < .01$. The correlation indicates that individuals' preference indexes on one block of trials predicted a significant amount of variance in the preference indexes of the next block ($r^2 = .42$). For Group B, the phase-space analysis revealed no consistency in individuals' preference indexes from block i to block $i + 1$, $r(46) = -.26$, $p > .05$. The phase-space analysis of the points gained by each participant in each block (Figure 10, lower panels) revealed a significant relation for Group A, $r(25) = .47$, $p < .05$, but not for Group B, $r(46) = -.26$, $p > .05$. To test whether preference affected points gained, the correlations between the two were calculated. The correlation between points and preference was significant for Group A, $r(34) = .66$, $p < .01$, and for Group B, $r(62) = .70$, $p < .01$. These two positive correlations reveal that individuals who preferred the richer card earned more points than those who preferred the leaner card.

Another measure of individual choice consistency entails the lagged correlation of participants' choices from trial to trial. Individuals' choices were coded as 1 for blue and 2 for red. An individual's trial was paired with the next trial, except for the last trial of a block and the first trial of the next block. An individual who chose the same card on every trial would produce a perfect positive correlation, and an individual who alternated on every trial would produce a perfect negative correlation. The results agreed with those shown in the upper panels of Figure 10. The average lagged correlation of choices for Group A was moderate ($r_{avg} = .61$), ranging from .07 to .88. The average lagged correlation of choices for Group B was moderate ($r_{avg} = .43$) and ranged from −.30 to 1.0.

To explore the degree of switching from trial to trial, we compared group-level measures of switching with individuals' recorded switching. The after-switch group numbers in Figure 6 show that both groups adjusted to each new point ratio in the early trials of each block and rarely switched thereafter. The records kept by individuals revealed that more switching occurred than the group data indicate. For Group A, out of the 56 comparisons that could be made, individual-level switching equaled group-level switching in 22 comparisons (39.3%). Individual-level switching exceeded the group-level measure by two switches in 28 comparisons (50.0%) and by four switches in four comparisons

←

Fig. 8. Histograms of the points individuals earned on every trial (including the first six) for every trial block of Experiment 2. The numbers on the x axis represent the upper limit of the bin (e.g., earning 10 points fell in the 10-point bin and earning 12.5 points fell in the 13-point bin). For each trial block, the point ratio is indicated.

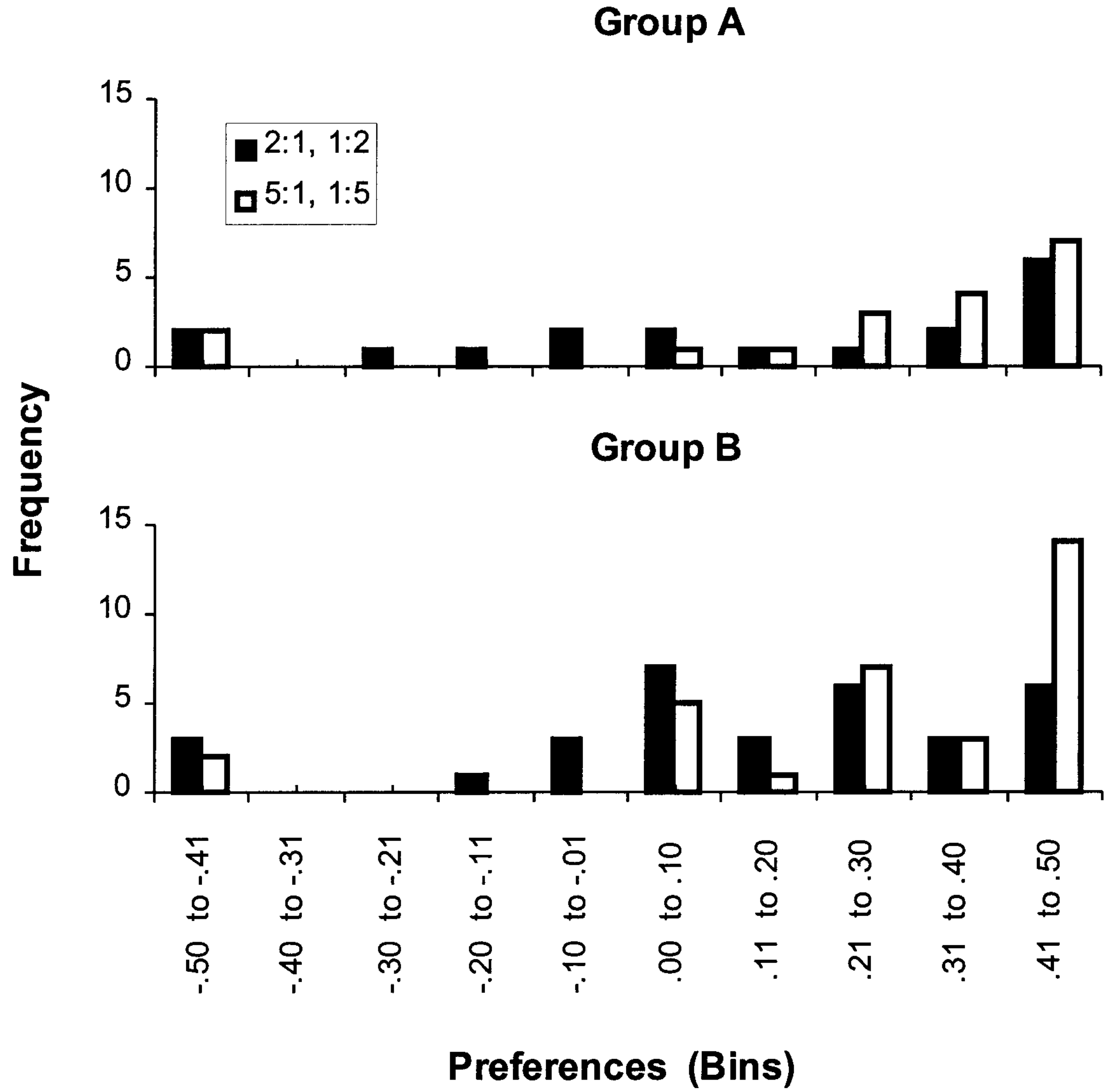


Fig. 9. Frequency distributions of individual preference indexes for Groups A and B in Experiment 2. An index of −.5 indicates exclusive preference for the card allocated fewer points, and an index of .5 indicates exclusive preference for the card allocated more points.

(7.1%). Two unclear cases were excluded. For Group B, individual-level switching equaled the group-level measure in 11 comparisons (19.6%), exceeded the group-level measure by two switches in 16 comparisons (28.6%), by four switches in 15 comparisons (26.8%), by six switches in nine comparisons (16.1%), and by eight switches in one comparison (1.8%). Four unclear cases were excluded. The disparity between the two levels of measurement reveals that individuals' switches often exceeded the minimum needed to observe switching on the group level.

Discussion

In the group-level analysis, both groups were sensitive to point ratios (Figure 7). Although both groups undermatched, choice ratios tended to track the point ratios in an orderly fashion. The groups' final choices (after-switch data) were similar enough that pooling the data had no effect on goodness

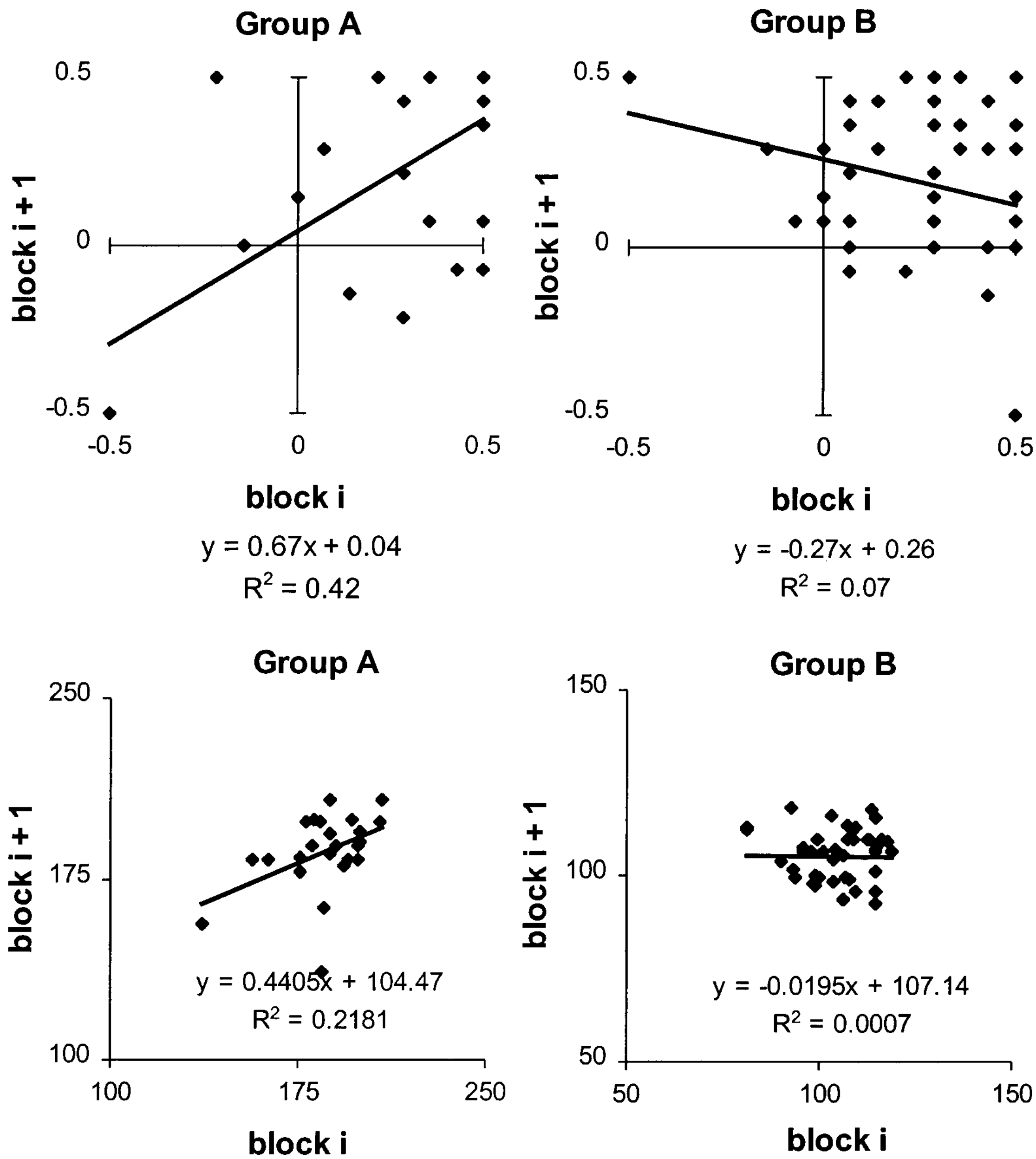


Fig. 10. Phase-space plots of individuals' preferences (top row) and points earned (bottom row) from trial block to trial block in Experiment 2. A high degree of consistency across individuals would appear as a positive correlation. Regression lines, fitted by the method of least squares, are shown, along with their equations and goodness of fit.

of fit. Experiment 2 groups undermatched more than the Experiment 1 group (Figure 2). Although the difference (.79 vs. .91) might just reflect the unsystematic process of participant selection that constituted the groups, it might also reflect the longer trial blocks of Experiment 1. Comparison of Figures 1 and 6 suggests that the additional trials in Experiment 1 may have further stabilized choice.

When the number of participants prevented perfect matching to the point ratio (7 of the 10 trial blocks for the two groups), group choice nevertheless tended to minimize the point discrepancy, as the IFD would predict. The discrepancy appeared, however, to be more easily minimized by having an extra person in the lean-card group (undermatching) than by having an extra person in the rich-card group (overmatching). In the four trial blocks in which undermatching by 1 minimized the point discrepancy, the groups undermatched on the majority of trials. In the three trial blocks in which overmatching by 1 minimized the discrepancy (the 2:1 and 1:2 point ratios for Group B), overmatching occurred in a majority of trials in only one trial block. The failure to overmatch might be attributed to the small difference in point discrepancy (0.7 for undermatching vs. 1.3 for overmatching) on those trials or to some sort of group dynamic that favored larger over smaller subgroups.

At the individual level, the results suggest that participants tended to act so as to optimize points earned. The main evidence for this is that, after the first block of trials, both groups tended to distribute so as to equalize the points earned per person or to minimize the difference between subgroups when equality was impossible (Figure 8, Table 2). The excess of switches recorded by the individuals over those evident in the group choices indicates that, when one person switched subgroups, another person would switch to compensate. Uniformity among the participants appeared, however, to cease there.

Individuals' preference indexes varied widely, as they did in Experiment 1, ranging from complete preference for the lean card to complete preference for the rich card (Figure 9). In the 5:1 rich:lean conditions, the modal preferences were strong for both groups, but in the 2:1 rich:lean conditions, Group A's modal preference was strong, whereas Group B's modal preference was weak. The groups also differed in the degree of consistency displayed by the individuals in them (Figure 10, upper graphs). Group A preference indexes showed a high degree of consistency from block to block of trials (r = .64), whereas Group B showed no consistency ($r = -.26$). These correlations illustrate that participants may be consistent or inconsistent in their preferences without affecting order at the level of the group. The groups were similarly inconsistent in points earned per individual (Figure 10, lower graphs), also without affecting the results at the group level. Both groups' preference indexes were related strongly to points gained (i.e., $r_A = .66$, $r_B = .70$), highlighting the benefit of choosing the richer card when the group undermatched.

GENERAL DISCUSSION

The two primary questions addressed were (a) whether the IFD might apply to human behavior (i.e., group choice) and (b) how group choice might be related to individual-level events. As in the study by Sokolowski et al. (1999), groups chose colored cards on each trial to earn points that led to possible cash prizes, and the points were distributed so that when more people raised a particular card, each received fewer points. The procedure thus was designed to meet the four assumptions of the IFD (Fretwell & Lucas, 1970) and to allow precise measurement of group choice (Figures 2 and 7).

The measures of sensitivity (a) and variance accounted for (r^2) found for the three groups of Experiments 1 and 2 showed an approximation to the IFD. The sensitivity measures ranged from .71 to .92, greater than the average sensitivity observed with foraging nonhuman animals (Kennedy & Gray, 1993) and greater than the sensitivity observed in other research of this type with humans (Sokolowski et al., 1999). All three groups showed, however, some tendency toward undermatching. In general, group choice approximated the point ratios, but slightly too few participants chose the rich card and slightly too many chose the lean card. Group choice was also extremely regular. The generalized IFD (Equation 3) accounted for nearly all the variance in group choice. In the after-switch data, Equation 3 accounted for more than 99% of the variance in all three groups' choices.

How can group choice be explained by the behavior of the individuals of the groups? During each block of trials after the first (Figures 3 and 8), all individuals tended to earn the same number of points. Although this might seem like cooperation, it may also be viewed as a by-product of individuals' optimizing their earned points. The histograms of points earned in Figures 3 and 8 suggest that most of the individuals were optimizing their earned points. More evidence came from the analyses of the groups' choices when the closest approximation to an IFD solution was to undermatch or overmatch by 1 individual. Both undermatching and overmatching led to a discrepancy between subgroups in points earned, but sometimes undermatching and sometimes overmatching led to the least discrepancy. In general, the groups chose the nonperfect IFD solution that minimized the discrepancy and thus roughly maximized each individual's points. Beyond this uniformity, however, it appeared that the groups' choices were unrelated to individuals' choices. The frequency distributions of individual preference spread over a wide range. Although most individuals had at least partial preference for the card with more points, some individuals exclusively preferred the card associated with fewer points. The distributions also were extremely skewed or bimodal, with no mode around the average (Figures 4 and 9). For example, when the group distributed in a 2:1 ratio, few of the individuals distributed in a 2:1 ratio. This variance in individual choice thus denies any possibility that group choice might just amount to individual choice writ large. It was still possible, however, that each individual played a fixed role, in the sense of maintaining a fixed preference. The phase-space analyses in Figures 5 and 10, however, revealed that no such consistency could be relied upon. In Experiment 2, Group A's preferences showed some consistency from block to block, but Group B's did not. Because the two groups were equally sensitive to point distributions, group-level order emerged whether or not there was consistency in individual preferences. In summary, the individual analyses showed that individuals optimized their earned points and produced group-level matching, but showed no other consistency.

No analysis of individual matching functions was undertaken, because in the experimental designs presented here, group-level matching forces individual-level matching to points obtained. A modified experimental design that breaks this relation (e.g., by awarding points only on some trials) could reveal relations between individual and group matching.

Future studies on the IFD with humans might benefit from a few improvements on the methods we employed. Although a comparison of group data with the aggregate of individuals' self-records revealed good correspondence, relying upon the participants' self-recording introduced the possibility of undetected recording errors. These errors could be eliminated by an independent measure of individual choices. The switching period might be unnecessary, judging from the high before-switch sensitivity measures. Eliminating the switching period might counter the suggestion that IFD matching occurs because participants engage in private verbal behavior (i.e., math) between before-switch and after-switch choices. Changing the point distribution from a shared method to a probabilistic method may show the relation between individuals' matching relations and the group's matching relation. If only some members of each subgroup were awarded points, then individuals' matching relations could be assessed with the generalized matching law (Baum, 1974, 1979). We have already conducted some studies along these lines (Kraft, 1999) and found that probabilistic point distribution reduced group-level sensitivity, but did make individual generalized-matching-law analyses possible. Our procedure might also be improved by providing fewer instructions and letting the contingencies of reinforcement shape the participants' behavior. In Experiment 1, we did nothing to keep the participants from talking between the first and second sessions, but the trends in IFD matching for Experiments 1 and 2 (with no chances to talk) appeared to be the same, which gives no reason to think that participants colluded. Still, experimenters might wish to prevent participants from discussing the experiment between sessions. We expect that improvements on our methods will provide even better data for IFD analysis.

Our approach, inspired by social foraging theory in behavioral ecology, was to analyze the behavior of the group as if the group were an individual. The IFD of foragers, suggested by Fretwell and Lucas (1970), was silent about the behavior of individual foragers in a group, except to assume that each forager would act so as to optimize its own gain. We found a high degree of order in the group process, but the only regularity we observed at the level of the individual participants was the tendency to maximize individual gain. This observation is not the same as saying there was no order in the individuals' behavior or that the group choice relations cannot be determined by individuals' behavior. We only mean that our efforts to find orderly individual behavior produced no noteworthy findings. Of course, another procedure or a different analysis might find the orderly individual behavior we sought. Further research will examine what behavioral patterns of individual participants, if any, underlie the ideal free distribution of human social behavior found here.

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