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INDIVIDUAL AND GROUP BEHAVIOR IN THE CENTIPEDE GAME: ARE GROUPS (AGAIN) MORE RATIONAL PLAYERS?

by

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Individual and Group Decisions in the Centipede Game: Are Groups More "Rational" Players?

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Abstract

Two experiments compared the Centipede game played either by 2 individuals or by 2 (3-person) groups. The 2 competitors alternate in deciding whether to take the larger portion of an increasing (or constant) pile of money, and as soon as one “takes” the game ends. Assuming that both sides are concerned only with maximizing their own payoffs (and that this is common knowledge), the game theoretic solution, derived by backward induction, is for the first mover to exit the game at the first decision node. Both experiments found that although neither individuals nor groups fully complied with this solution, groups did exit the game significantly earlier than individuals. The study of experimental games has uncovered many instances in which individuals deviate systematically from the game theoretic solution. This study is in accord with other recent experiments in suggesting that game theory may provide a better description of group behavior.

Individual and Group Decisions in the Centipede Game:

Are Groups More “Rational” Players?

The logic of backward induction applies most directly to two classes of interactive decision-making problems. One includes repeated games with a finite and commonly known number of repetitions. The other encompasses games with perfect information where the players move one at a time in full knowledge of all preceding moves. Assuming that all players are “*rational”*, in the sense that each is concerned only with maximizing her own payoffs, and that their “rationality” is *common knowledge* -- that is, each player knows that all are “rational” and knows that the others know it, and so on (Colman, 1995)-- the game theoretic solution to both types of games is derived by reasoning backward through the game tree.

For example, consider the iterated two-person Prisoner’s Dilemma game. When the number of rounds to be played is finite and commonly known, selfish players who seek only to enhance their own payoffs should defect in the last round (since defection results in higher payoffs, *regardless* of what the other player does). Knowing that, the players should also defect in the next-to-last round, and the round before that, and so on. Thus, the argument of backward induction prescribes defection by both players in all rounds of the game, including the first round. This argument, while logically compelling, fails utterly to account for choice behavior observed in the laboratory, as demonstrated by numerous experiments (e.g., Andreoni & Miller, 1993; Hahn & Murningham, 1993).

Another well-known example of the failure of the backward induction argument to describe actual choice behavior is the two-person Centipede game (Rosenthal, 1981), which is the focus of the present investigation. The Centipede is a game with perfect information where the two players alternately get a chance to take the larger portion of a continually growing pile of money. As soon as a player "takes", the game ends with that player getting the larger portion of the pile, while the other player gets the smaller portion. Passing decreases a player's payoff if the opponent takes the larger portion on the next move. If the opponent also passes, the two players are presented with the same choice situation with increased payoffs. The game has a finite number of moves, which is commonly known to both players.

Consider the Centipede game in Figure 1. At each decision node a player has to decide between Take and Pass. If Player 1 chooses Take, the game ends and the players are paid the payoffs at the first terminal node. If Player 1 chooses Pass, the game progresses to the second decision node, where it is Player 2's turn to decide between Take and Pass, and so on. At the final decision node, the game terminates whether Player 2 chooses Take or Pass. Clearly, at this final node, Player 2, as a selfish payoff-maximizer, should choose Take, since Take results in a payoff of 75 while Pass pays only 66. Assuming that Player 2 is selfish and therefore will choose Take at the last decision node, Player 1, who is similarly selfish, should choose Take at the next-to-last node, and receive 65 instead of only 56. Since the same logic can be applied to all moves up the game tree, Player 1 should choose Take at the first decision node.

<Insert Figure 1 about here>

Nonetheless, studying choice behavior in different versions of the Centipede game, McKelvey and Palfrey (1992) found that players rarely followed this game-theoretic prescription. Specifically, McKelvey and Palfrey employed a four-move, a six-move, and a high-payoff version of the Centipede game and found that only in 7% of the four-move games, 1% of the six-move games, and 15% of the high-payoff games did the first player choose Take on the first move. Similar results were reported by Nagel and Tang (1998) and by Parco, Rapoport, and Stein (2002).[1]

One explanation for this apparent gap between the observed behavior and the theoretical prediction maintains that the subject pool contains two types of players, "altruistic" and selfish (McKelvey & Palfrey, 1992). "Altruistic" or pro-social (e.g., van Lange, 1999) players attempt to maximize the joint payoffs of both sides (McClintock, 1972), and therefore will always choose Pass. Selfish players attempt to maximize their own expected payoffs, given their beliefs about the other players. If they believe that all the other players are also selfish (and that the others know that, and so on), they should choose Take at the first opportunity as game theory prescribes. However, if they believe that some of the others are "altruists" (or pro-social), they have an incentive to mimic "altruistic" behavior by passing with some probability in the early stages of the game and increasing the stakes. As argued by McKelvey & Palfrey (1992), "these incentives to mimic are very powerful, in the sense that a very small belief that altruists are in the subject pool can generate a lot of mimicking, even with a very short horizon" (ibid., p. 805).

Another explanation suggests that, faced with a novel and rather artificial task, some participants may make mistakes. Mistakes may result from misapprehension of the game's rules (e.g., failing to see that the game can end right away, confusing which player they are, mixing-up the payoffs, etc.). Mistakes may also result simply from "noisy" play such as pressing the wrong key or some other random event. Assuming that other players may make mistakes, selfish players can delay Take in order to exploit the situation and increase their own payoffs (Fey, McKelvey, and Palfrey, 1996).

Group decisions in the Centipede game

The experimental research on the Centipede game has focused exclusively on individual behavior. The goal of the present paper is to examine how groups act in this game. Studying group behavior is important since the decision agents in many real-life strategic situations are groups (e.g., families, boards of directors, committees, governments), and group behavior is not readily inferred from individual-level experiments (e.g., Davis, 1992; Kerr, MacKoun and Kramer, 1996).

To achieve this goal, we compared the behavior of individuals with that of three-person groups. The members of each group could communicate freely to decide between Take and Pass at each node of the game. As the game ended, each player received an equal share of their group's payoff (the group's payoff was three times the payoff in the individual condition). Since the strategic structure of the Centipede game is not affected by this manipulation, the "rational", game-theoretic solution for the two conditions is identical -- for the first mover, whether an individual or a group, to choose Take at the first node. We already know that individuals do not act this way; the question we are focusing on here is whether group behavior is different from individual behavior.

Experiment 1: Increasing – sum game

Method

Participants: The participants were 144 undergraduate students at the Hebrew University of Jerusalem with no previous experience with the task.[2] The participants were recruited by campus advertisements offering monetary rewards for participating in a decision task. Thirty-six subjects participated in the individual condition (in 6 cohorts of 6 participants) and 108 subjects participated in the group condition (in 6 cohorts of 18 participants).

Procedure: The Centipede game, as operationalized in the experiment, is shown in Figure 1. The payoffs are in New Israel Shekels ($1 = approximately NIS 4.5 at the time of the experiment). The game was played once.

Individual condition: Upon arrival at the laboratory the participants were given verbal instructions on the rules and payoffs of the game, and a quiz to test their understanding. The participants were told in advance that their decisions and their eventual payments would remain confidential. The 6 participants in each cohort were randomly divided into 3 pairs. In each pair, one participant was randomly named the red player (Player 1) and the other the blue player (Player 2). The participants did not know the identity of the player with whom they were matched. Each player was seated in a separate room facing a personal computer where she entered her decisions and received information on the decisions of her opponent. Following the completion of the experiment, the participants were debriefed on the rationale and purpose of the study. They were then paid in sealed envelopes outside the laboratory and dismissed individually with no opportunity to interact with the other participants.

Group condition: The 18 participants in each cohort were randomly divided into 3 pairs of three-person groups. In each pair of groups, one group was randomly designated the red player (Player 1) and the other the blue player (Player 2). Each group was seated in a separate room that allowed for private discussions. No specific instructions were given as to how the group decision should be made. Half of the group sessions were audio-taped, with the explicit knowledge and consent of the participants. As in the individual condition, each group used a computer to enter its decisions and receive information on the decisions made by the other group. The payoffs in Figure 1 represents the payoffs for *each* individual group member in this condition. In all other details the procedure in the group condition was identical to that in the individual condition.

Results and discussion

Table 1 presents the frequency of games ending at each of the seven decision nodes in the individual and group conditions. The average terminal node in the individual condition is 5.22, with 88% of the games ending at the fifth decision node or later. The average terminal node in the group condition is 4.44, with 55% of the games ending at the fourth decision node or earlier.[3] The difference between the two distributions is statistically significant by a robust rank-order test ($\grave{U} = 2.36$, $p < 0.01$).

<Insert Table 1 about here>

How can these results be explained? One possibility is that groups are less pro-social (less “altruistic”) than individuals. The tendency of groups to behave in a more selfish or less cooperative way than individuals has already been substantiated in the two-person Prisoner’s Dilemma game (Insko & Schopler, 1987; Schopler & Insko, 1992). Insko and Schopler (See, e.g., Wildschut, Pinter, Vevea, Insko, & Schopler, in press) offer three explanations for this observed difference, termed the “discontinuity” effect. The "social support for shared self-interest" hypothesis argues that groups are more competitive than individuals because group members provide each other with support for acting in a selfish, ingroup-oriented way. The *identifiability* explanation proposes that intergroup interactions are more competitive because the other side’s ability to assign personal responsibility for competitive behavior is more limited. Finally, the "schema-based distrust" hypothesis postulates that group members compete because they expect the outgroup to act selfishly and want to defend themselves against the possibility of being exploited. As a result of these processes, groups are more selfish than individuals and expect their opponents to behave more selfishly, which would explain why they terminate the Centipede game earlier than individuals.

The inclination of groups to be more selfish or greedy than individuals is clearly demonstrated by their behavior at the end of the game. As can be seen in Table 1, three of the four individuals (in the role of Player 2) who arrived at the last decision node (i.e., node 6) decided to pass, giving the larger pile of money to the other player. In contrast, all three groups arriving at this last node decided to stop, taking the larger pile for themselves. At the post-experimental debriefing we asked the three individuals who chose Pass to explain their "irrational" choice. All three provided essentially the same explanation. Since Player 1's cooperation is what enabled them to reach the last (and most profitable) node, they felt obligated to reciprocate (e.g., Cialdini & Trost, 1998). The structure of the game presented them with a rather cost-effective way of doing so, since by choosing Pass at the last node they could increase the payoff of Player 1 by NIS 29 at a cost of only NIS 9 to themselves.

Groups were obviously much less constrained by such considerations. We happen to have the recordings of two (of the three) groups which arrived at the sixth decision node. The content of group discussions at this last node indicates that group members were fully aware of the monetary consequence of their decision and its "moral" implications (e.g., "It would be nice to choose Pass, it doesn't matter much for us whether it's NIS 75 or 66, but for them it's significant"; and, following a Take decision: "Now they must be mad at us"). Nevertheless, as maintained by the "social support" hypothesis (e.g., Wildschut et al, in press), when a single group member recommended the selfish (Take) course of action (e.g., "We want to make 75 Shekels and not just 66"; "There is no division of profits afterwards") the others willingly followed suit. Moreover, to uphold their decision, group members came up with arguments which questioned the cooperative intentions of the outgroup (e.g., "I was sure they're going to stop, maybe they got confused"), and defended the morality of the ingroup's decision (e.g., "We were generous all the way, only now we made a decision in our favor".)

There was also some evidence which supports the "identifiability"or "group membership as a shield of anonymity" explanation. As observed by Wildschut, et al. (in press), groups are more competitive because "group members can escape the appearance of selfishness by claiming that their competitive behavior was prompted by other group members." The following excerpt from one of the group discussions (following a Take decision at node 6) clearly illustrates this point ("We made the right decision, I feel great! I'd feel better if we had chosen Pass. Do you regret the decision? No, because it wasn't only mine. It's a group thing.")

Two additional features of the data need to be discussed. First, in neither the individual nor the group condition did the game end at the first or second decision node. In other words, neither Player 1 nor Player 2 chose Take at their first opportunity, as prescribed by game theory. The contents of the group discussions indicate that group members generally believed that, given the relatively low payoffs at the beginning of the game, the other group was not likely to exit the game at the first or second node ("If they stop at the beginning, we've had it", "No way, they won't stop before [node] 3"; "I think they'll stop on [node] 1", "No, it's not worth it"). One can only infer from their observed behavior that individual players hold similar beliefs.

Finally, since games played by individuals were terminated later than games played by groups, the average joint payoff in the individual condition was higher than that in the group condition (NIS 115.44 and NIS 99.89 respectively, robust rank-order test, Ù=2.36, $p<0.01$). Incidentally, the entire surplus generated in the individual condition went to Player 1. The mean payoff for Player 1 in the individual condition was significantly higher than that in the group condition (NIS 65.11 and NIS 48.89 respectively, robust rank-order test, Ù=4.57 , $p<0.01$), whereas there was no significant difference between the two conditions in the payoffs of Player 2 (NIS 50.33 and NIS 51.00, respectively, robust rank-order test, Ù =-0.68, ns).[4]

Experiment 2: Constant-Sum Game

Experiment 1 found that groups exit the increasing-sum Centipede game earlier than individuals. A plausible explanation for this result, which the contents of the group discussions seem to corroborate, is that groups are less "altruistic" (less concerned with maximizing the joint gain and more concerned with maximizing their own outcome) than individuals. However, Experiment 1 cannot rule out the possibility that part of the explanation for why groups terminate the game earlier than individuals is that they are less prone to making mistakes. Extensive social psychological research demonstrates that for certain kind of tasks "several heads are better than one." This is particularly true in simple decision tasks where, if the correct solution is raised, it is immediately clear that it is indeed correct (Lorge, Fox, Davitz and Brenner, 1958; Kerr, MacKoun and Kramer, 1996). Groups are therefore less likely than individuals to misapprehend the rules of the Centipede game, misunderstand which player they are, press the wrong key, or make other mistakes.

Moreover, groups probably know that other groups are not very likely to make mistakes.

To investigate this possibility, Experiment 2 employed a Centipede game, where the sum of payoffs for the two players is constant at each terminal node. Thus, unlike the increasing-sum game studied in Experiment 1, passing in the constant-sum game does not increase the joint payoffs of the two sides, and the predictions of the "rational" and "altruistic" models (as well as fairness considerations) coincide. Put simply, regardless of whether the participants seek to increase their own outcome (individualistic orientation), or the joint outcome along with equality (prosocial orientation), they should exit the game at the first node.[5] The only conceivable explanation for players not doing so is that they are making mistakes (or are assuming that others may make mistakes).

<Insert Figure 2 about here>

Indeed, studying constant-sum Centipede games of various lengths, Fey et al. (1996) found that fewer than half of the observations corresponded to the game-theoretic solution. To explain their data, Fey et al. suggested a model which accommodates action errors by players. In this model, sophisticated players attempt to maximize their own expected payoffs while assuming that other players may make mistakes in their choice of action.

If the difference between group and individual behavior found in Experiment 1 is due entirely to the fact that groups are less "altruistic" or pro-social than individuals, then no difference will be found in Experiment 2. However, if some of this difference is due to the possibility of errors, and players actively adjusting their behavior to take advantage of these errors, one would expect groups to terminate the constant-sum game earlier than individuals. Groups, as discussed above, are expected to make fewer errors and to be aware of this fact.

Method

Participants: The participants were 144 undergraduate students at the Hebrew University of Jerusalem who had not participated in Experiment 1. The recruitment and design were identical to those of Experiment 1.

Procedure: Figure 2 depicts the constant-sum game. By choosing Take on the first move, Player 1 and Player 2 get NIS 48 each and the game ends. If Player 1 chooses Pass, the joint payoff remains the same and it is Player 2's turn to decide between Take, which pays NIS 56 to Player 2 and NIS 40 to Player 1, and Pass. This continues for at most six moves. At the last decision node Player 2 can take NIS 88 (leaving 8 to Player 1), or pass and leave the whole pile of NIS 96 to Player 1.

Results and discussion

Table 2 presents the proportion of games ending at each of the seven decision nodes. The average terminal node in the individual condition is 2.56, with 50% of the games ending at the first or second node. The average terminal node in the group condition is 2.00, with 83% of the games ending at the first or second node.[6] The difference between the two distributions, while smaller than that found in Experiment 1, is statistically significant by a robust rank-order test ($\grave{U} = 1.7$, $p < 0.05$).

<Insert Table 2 about here>

Two aspects of these data are particularly informative. First, the finding that groups terminate the constant-sum game earlier than individuals lets us conclude that groups make fewer mistakes than individuals.[7] Second, the fact that both groups and individuals terminate the constant-sum game earlier than the increasing-sum game indicates that both types of players have other-regarding preferences. Moreover, since the difference between groups and individuals in Experiment 2 is smaller than that found in Experiment 1, it seems that both explanations are pertinent. That is, groups are both less pro-social and less prone to errors than individuals.

Finally, in the constant-sum game there are no joint benefits in choosing Pass and thus the fact that individuals terminated the game later than groups did not increase the joint payoff. Incidentally, in both conditions Player 2 earned more than Player 1. The mean payoff for Player 2 was 51.55 and 52.44 in the individual and group conditions, respectively, while the mean payoff for Player 1 in these two conditions was only 44.44 and 42.2.[8]

General Discussion

We compared individual and group behavior in the increasing-sum and constant-sum Centipede games and found that in both cases groups terminate the game significantly earlier than individuals. Based on these results, we concluded that groups are less pro-social than individuals (and assume that other groups are similarly motivated) and less prone to errors (and assume that other groups are also less likely to make mistakes). Stated more generally, groups are more "rational" (in the game-theoretic or economic sense) than individuals and more likely to assume common knowledge of "rationality".[9]

Are Groups Generally More "Rational" Players?

With the exception of the "discontinuity" research described earlier, the vast majority of experiments on strategic games have employed individuals as the decision-making agents. However, several recent studies have compared the interactive behavior of individuals with that of groups (whose members communicate freely and arrive at a single binding decision). Bornstein and Yaniv (1998) studied behavior of individuals and groups in the one-shot Ultimatum game. In this game

Player 1 has to propose a division of a sum of money between herself and Player 2. If Player 2 accepts the proposed division both are paid accordingly; if Player 2 rejects the proposal, both are paid nothing. The game-theoretic solution for this game is again based on backward induction. Knowing that Player 2, as a “rational”, self-interest maximizer, should accept any positive proposal, Player 1, who is similarly motivated, should propose to keep all but a penny for herself. Bornstein and Yaniv (1998) found that, although neither individuals nor groups were fully “rational” in that sense, groups in the role of Player 1 offered less than individuals, and groups in the role of Player 2 were willing to accept less. Similar findings about the behavior of Player 1 were reported by Robert & Carnevale (1997).

An experiment by Cox (2002) compared individual and group behavior in the Trust game (Berg, Dickhaut, & McCabe, 1995). In this game Player 1, the sender, receives an initial amount of money and can send any part of it to Player 2, the responder. The amount sent is tripled and Player 2 can return any part of the tripled sum to Player 1. The game-theoretic solution is again clear. Since a selfish Player 2 should return nothing regardless of how much she received, Player 1, who is also selfish, should send nothing in the first place. However, this outcome minimizes the joint outcome of the two players (and is thus collectively deficient). In a scenario that is both efficient and fair, player 1 sends the whole amount, and player 2 returns half of the tripled sum. Cox (2002) found that, while there was no significant difference between group and individual senders, groups in the responder role returned smaller amounts than individuals.

Kocher and Sutter (2002) studied individuals and groups in a one-shot Gift-Exchange game. The game models bargaining in the labor market, where the employer first determines the employee’s wage, and the employee then chooses her effort level. Assuming that the level of effort is not stipulated in the contract, the employee should exert minimum effort regardless of her “wage” and, anticipating that, the employer should pay the lowest possible wage. Kocher and Sutter (2002) found that groups chose smaller wages and effort levels than individuals.

Whereas these experiments indicate that groups are more selfish (or narrowly rational in the economic sense) than individuals, there is also some evidence which suggests otherwise. Cason and Mui (1997) found that (two-person) groups made more generous, other-regarding allocations in the dictator game than individuals, and were thus further away from the game-theoretic prediction. The dictator game is a one-sided ultimatum game where player 1 has to divide a sum of money between herself and player 2, and player 2 must accept the division. Thus, unlike the other experiments, Player’s 1 assumptions about Player 2 are irrelevant.

Summarizing this experimental evidence, it seems clear that groups and individuals make different decisions in strategic games and, more often than not, group decisions are closer to the “rational” solution. This seems particularly true when the solution is derived by backward induction and assumes a common knowledge of “rationality”. The research on experimental games has uncovered many instances in which individuals deviate systematically from the game-theoretic prediction. Is game theory a better description of group behavior?

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Footnotes

[1] Although Rapoport, Stein, Parco, & Nicholas (2000) found that, in a Centipede game with three players and very high stakes, participants behave more in accord with the game-theoretic solution.

[2] 65% of the 288 participants in the two experiments were females.

[3] There was no difference between the behavior of groups that were audiotaped and those that were not. The mean terminal node for both conditions was exactly 4.44.

[4] This outcome is incidental since, had all the players (individuals and groups) terminate the game one node earlier, Player 2 would have earned more. The mean payoff for Player 2 in that case would have been 55.11 in the individual condition and 38.38 in the group condition, while the mean payoffs for Player 1 would have been 40.33 and 41.00 in the individual and group conditions, respectively.

[5] Of course, if the participants are purely altruistic, in the sense that they wish only to maximize the other player's payoffs, they should choose "Pass". If, on the other hand, subjects are competitive, attempting to maximize their relative payoff, the prediction is less clear. Passing can increase the relative advantage if the opponent also passes, but it can also result in a relative disadvantage if the opponent stops.

[6] Again, there was no significant difference between the behavior of groups that were audiotaped and those that were not. The mean terminal node for the first condition was 1.77 and for the second 2.22 (Ù = 1, ns).

[7] Group discussion provided some informal support for the model suggested by Fey et al. At least in one case, group members decided to pass at node 1 while explicitly assuming that the other group would make a mistake ("It's clear that they

should stop at [node] 2 if they are playing right, but the chances that they will stop are really small.”)

[8] Again, this effect is incidental, and if, for example, the game had stopped one node later, it would have been reversed. Player 1 would have earned 52.44 and 55.11 in the individual and group conditions, respectively, and Player 2 would have earned 43.56 and 40.89.

[9] Nevertheless, these experiments do not allow us to determine the extent to which groups exit the game earlier than individuals because they are more “rational” actors, or because they assume that other groups are more “rational” and therefore cannot be exploited. A possible way to assess which part of the observed difference depends on the type of the decision-maker and which on the decision maker’s beliefs about the opponent is to study a Centipede game where groups and individuals play against each other. Although studying such asymmetric games could probably shed more light on this issue, it cannot provide a definitive answer, since what would be studied are beliefs of groups about ‘individuals playing against groups’ and vice versa.

Table 1

Frequency of Games Ending at Each Decision Node in the Increasing-Sum Game.

Node	1	2	3	4	5	6	7
Individuals	0	0	1	1	12	1	3
Groups	0	0	3	7	5	3	0

Table 2

Frequency of Games Ending at Each Decision Node in the Constant-Sum Game.

Node	1	2	3	4	5	6	7
Individuals	3	6	5	4	0	0	0
Groups	4	11	2	1	0	0	0

Figure Caption

Figure 1: The increasing-sum Centipede game. Player 1's decision nodes are denoted by squares, and Player 2's by circles. The upper payoff at each terminal node is the payoff of Player 1.

Figure 2: The constant-sum Centipede game: Player 1's decision nodes are denoted by squares, and Player 2's by circles. The upper payoff at each terminal node is the payoff of Player 1.

Figure 1

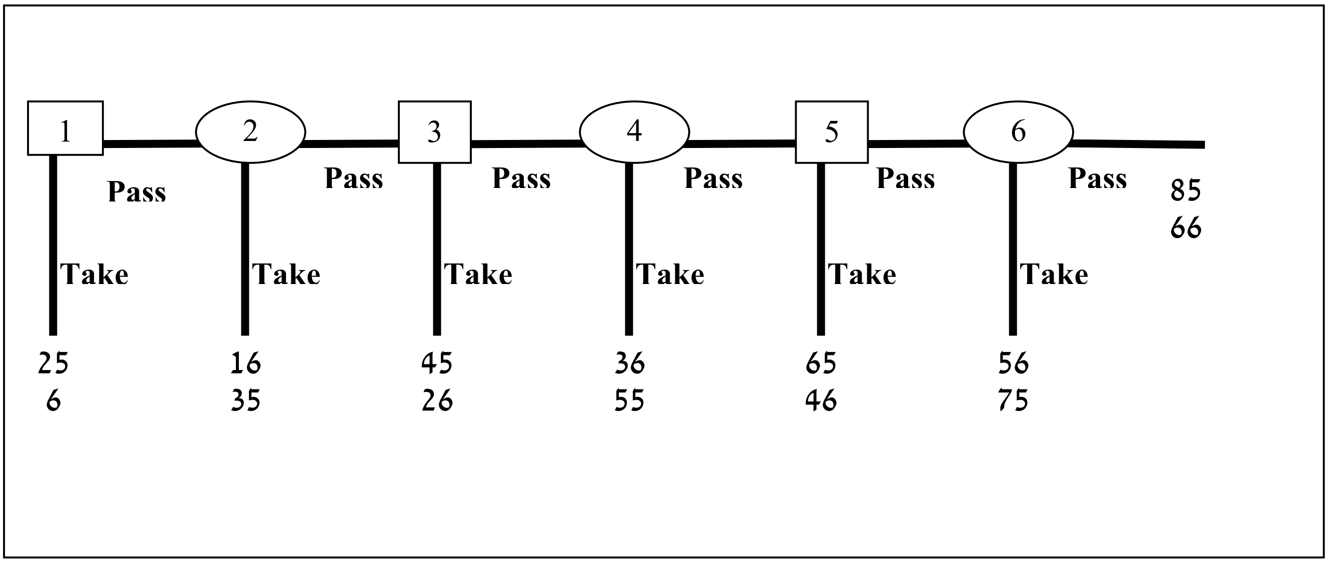
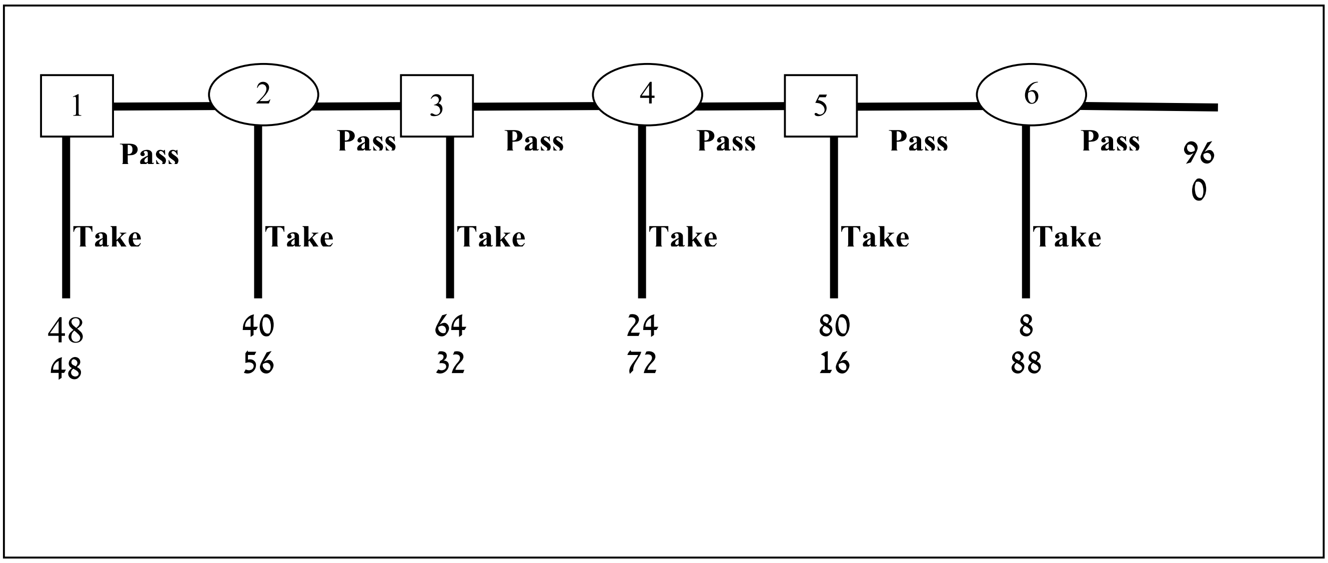

1
2
3
4
5
6
Pass
Pass
Pass
Pass
Pass
Pass
85
66
Take
Take
Take
Take
Take
Take
25
6
16
35
45
26
36
55
65
46
56
75

Figure 2


1
2
3
4
5
6
Pass
Pass
Pass
Pass
Pass
Pass
96
0
Take
Take
Take
Take
Take
Take
48
48
40
56
64
32
24
72
80
16
8
88