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Cognitive Biases in Playing the Lottery: Estimating the Odds and Choosing the Numbers

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Three experiments were conducted to examine the operation of the representativeness and anchoring and adjustment heuristics in lottery play. Subjects in Experiments 1 and 2 indicated their chances of winning a lottery with an objective probability of 1 in 10. Consistent with the anchoring and adjustment heuristic, subjects (in both experiments) perceived their chances of winning to be greater when the lottery was based on a single event than when it was based on a disjunctive event. Subjects in these two experiments also selected numbers to play in a pick-3 (Experiment 1) or pick-4 (Experiment 2) lottery. Consistent with the representativeness heuristic, subjects in Experiment 2 demonstrated a preference for numbers without repeating digits. This also occurred in Experiment 3 wherein the numbers actually played in the Indiana daily Pick-3 lottery were examined.

The 1980s were a decade of lottery mania. By 1990, 32 states and the District of Columbia had active lotteries with a total yearly gross of over 20 billion dollars (Kaplan, 1990). Moreover, between 60 and 80% of the population in states with lotteries reported playing a lottery at least once (Kaplan, 1990). Lottery play, then, is probably the most common form of gambling in the United States, and thus deserving of systematic study. In this research we empirically examined several cognitive biases that may be involved in lottery play.

Cognitive Biases and Lotteries

A number of writers have argued that persistence at gambling (despite inevitable losses) is due to the operation of several cognitive biases (Corney & Cummings, 1985; Griffiths, 1990; Wagenaar, 1988). For example, empirical research has demonstrated the existence of an illusion of control whereby individuals perceive chance activities as if they were determined by skill (Langer, 1975), at least for small wagers (Dunn & Wilson, 1990). Other research has demonstrated biased evaluations in

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gambling such that people discount their losses but accept their wins at face value (Gilovich, 1983; Gilovich & Douglas, 1986). Although some of these biases may operate in lottery play (e.g., the opportunity to choose lottery numbers, rather than have them assigned, may induce an illusion of control), they are more likely to operate in gambling situations that involve a skill component. Lotteries generally do not have this feature. Lottery play, however, does involve decisions (e.g., choosing which lottery to play, choosing which numbers to play, etc.), and these decisions may be affected by certain decision-making heuristics. Two of the heuristics described by Tversky and Kahneman (1974), representativeness and anchoring and adjustment, have clear implications for lottery decisions.

Representativeness

The representativeness heuristic refers to a tendency to judge the probability of an event based on the extent to which the event is similar to a parent population; the more similar the event is to the population, the higher the perceived probability that it comes from that population. This heuristic has been used to explain a number of biases such as the tendency to neglect base rate information (Kahneman & Tversky, 1972), the disregarding of sample size (Bar-Hillel, 1979), and insensitivity to source reliability/credibility (Kahneman & Tversky, 1973).

Of particular interest here is the role of representativeness in (mis)conceptions of chance. There appears to be a tendency for people to judge the randomness of an outcome as a function of its irregularity and local representativeness (Kahneman & Tversky, 1972). That is, outcomes will be judged random if the outcome appears irregular (Tune, 1964) and reflects the parent distribution. Thus, in a coin toss the sequence HTHHTHT will be (erroneously) judged more random than the sequence HHHHTTT.

The representativeness heuristic underlies the gamblers' fallacy, or belief that subsequent events will cancel out previous events so as to produce a representative (i.e., random) sequence (even in the short run). This has been found to operate in actual gambling situations. For example, Metzger (1985) found horse track betters to overestimate the chances of favorites after a series of races had been won by long shots. Wagenaar (1988) reports that the betting patterns of some blackjack players (those who increase their bets after a series of losses) and the playing decisions of some roulette players (those who bet on numbers that lost previously) are sometimes consistent with the operation of the representativeness heuristic.

One manifestation of the representativeness heuristic in lottery play is a player's selection of numbers. In most lotteries players select numbers on which they will wager. Winning occurs when the numbers selected by the player match (at least a portion of) the numbers selected by the lottery operator. Although any number is as good as any other number—lotteries are, after all, random—there may be a systematic bias in the numbers chosen for play. According to the representativeness heuristic, there should be a tendency for people to choose numbers that "appear" to be random. Numbers that appear random will be those that appear irregular and locally representative. Because numbers with repeating digits (e.g., 444) appear to violate this belief about randomness, lottery players should tend to avoid choosing them. Instead, players should show a preference for numbers without repeating digits (e.g., 145).

Anchoring and Adjustment

People sometimes make a judgment by starting with an initial estimate (based on salient features of the task, past experience, etc.), and then adjust the initial estimate to arrive at a final judgment. This heuristic can result in a biased judgment because too much weight may be placed on the initial anchor, and the subsequent adjustment is insufficient (Tversky & Kahneman, 1974).

There is some evidence for the operation of this heuristic in lottery play. For example, Wagenaar (1988) found that subjects' judgments of lotteries were based on an anchoring point that was then insufficiently adjusted for the actual properties of the lottery. The anchoring and adjustment heuristic may also play a role in preferences for certain lotteries. When a lottery involves multiple events (i.e., the selection of more than a single number) players' estimates of winning may be biased because the adjustment following the initial estimate (based on a single event) is insufficient. Consider, for example, a lottery that is a conjunctive event (e.g., correctly selecting a number between 0 and 9 three times in succession). Estimates of winning may be a result of an initial anchor (based on a single stage) that is then adjusted to accommodate the probability of three successes in a row. If people fail to adjust sufficiently, the perceived odds of winning in this case should be inflated. This is because the probability of a conjunctive event is less than the probability of the individual states (Bar-Hillel, 1973). On the other hand, if the lottery is a disjunctive event (e.g., correctly selecting at least one number between 0 and 9 in three tries), the estimated probability of winning should be lessened because the probability of a disjunctive event is greater than the probability of each individual stage. Thus, given lotteries with identical probabilities, people should believe they are more likely to win a lottery based on a conjunctive event than a lottery based on a single event. Similarly, they should believe they are more likely to win a lottery based on a single event than a lottery based on a disjunctive event. It should be noted, in this regard, that all lotteries in the United States of which we are aware are conjunctive events. There are, however, lotteries in Europe that are disjunctive events.

There is a different heuristic that is also relevant for lotteries. According to the simulation heuristic (Kahneman & Miller, 1986) people's reactions to events are based, in part, on possible alternative events that can be brought to mind (i.e., simulated). Accordingly, people should experience more regret for a negative outcome the more easily they can imagine alternative actions that would have resulted in a positive outcome. Recently, Miller, Turnbull, and McFarland (1989) provided evidence that the ease with which an event can be simulated also affects judgments of the likelihood of the event occurring. They found that judgments of suspiciousness for an outcome were higher the more difficult it was to imagine the outcome. For example, subjects predicted that someone who rented a car that broke down would be more suspicious of a company that claimed 2 out of their 20 cars are defective, than they would be of a company that claimed 20 out of their 200 cars are defective. The odds of getting a faulty car are the same in each case; however, it is presumably more difficult to imagine getting a faulty car when there are only 2 (rather than 20) ways for this to happen, and hence subjects are more suspicious (i.e., less likely to believe the outcome is due to chance).

To the extent that this heuristic can be applied to lotteries, it suggests that people should overestimate the odds of winning a lottery in which they can easily imagine a positive outcome. For example, if a player needs to match only one of the selected numbers in a lottery (a disjunctive event), then this should increase the ease with which a positive outcome can be imagined (i.e., there are more ways to win), and hence inflate the perceived odds of winning. Note, however, that this prediction (the perceived odds are greater for a disjunctive lottery than for a conjunctive lottery) is the opposite of what would be predicted by the anchoring and adjustment heuristic. One of the purposes of this research was to test these competing predictions.

Experiment 1

We used both real and hypothetical lotteries to examine the cognitive biases outlined above. First, to examine the anchoring and adjustment versus simulation heuristics, we developed two versions of a lottery in which the chances of winning were identical (1 in 10), but the procedures differed. In one lottery (termed the 1/10 lottery), the player and lottery operator each select a single number between 1 and 10, and the player wins if the numbers match (a single event). In the other lottery (termed the 10/100 lottery), the player selects a number between 1 and 100, and the lottery operator selects 10 numbers from between 1 and 100 without replacement. The player wins this lottery if his or her number matches any one of the 10 numbers chosen (disjunctive event). We asked subjects to read descriptions of one of these two lotteries, and to then indicate their chances of winning. Even though the probability of winning is the same, the anchoring and adjustment heuristic predicts that subjects will perceive their chances to be greater for the 1/10 lottery than for the 10/100 lottery. In contrast, the simulation heuristic suggests that subjects will perceive their chances of winning to be greater for the 10/100 lottery than for the 1/10 lottery. Because the perceived likelihood of winning may affect other aspects of lottery play, we also asked subjects to indicate their likelihood of playing either the 1/10 or 10/100 lottery, how much they would wager, and how long they would continue to play if they continued to lose.

Second, we used the Indiana Pick-3 lottery to examine the representativeness heuristic. In this lottery a player chooses three 1-digit numbers between 0 and 9. Players win (the payoff is 500 for 1) if their numbers match (in sequence) the three numbers selected in the lottery drawing. This lottery was described for the subjects and they were asked to indicate which three-digit number they would play. We also presented subjects with a list of three-digit numbers and asked them to indicate which of these numbers they would be most likely to play. Based on the representativeness heuristic, we expected (for both measures) numbers without repeating digits to be overplayed and numbers with repeating digits to be underplayed.

Method

Subjects

A convenience sample of 34 introductory psychology students (16 males and 18 females) participated in this study. They received partial course credit for their participation. Importantly, a majority (82.4%) of these students reported having played a lottery before.

Hypothetical Lottery Questionnaire

Two versions of a lottery were written in which the odds were the same but the procedure varied (see Appendix A). In one lottery (termed the 1/10 lottery), the player selects a number between 1 and 10. The operator then randomly selects a number between 1 and 10. The player wins if the number he or she selected matches the number selected by the operator. In the second lottery (termed the 10/100 lottery), the player selects one number between 1 and 100. The operator then selects 10 numbers without replacement between 1 and 100. The player wins if his or her chosen number matches any one of the 10 selected numbers.

After reading one of these two lotteries, subjects indicated: (a) their perceptions of how *likely* it is that they would win this lottery (1 = extremely unlikely to 7 = extremely likely); (b) their estimated chances (between 0% and 100%) of winning this lottery; (c) how *likely* it is that they would play this lottery (1 = extremely unlikely to 7 = extremely likely); (d) how much they would wager (between $1 and $10); (e) how many losses would need to occur before they would stop playing this lottery; and (f) how *clear* the lottery procedure was (1 = extremely unclear to 7 = extremely clear).

Pick-3 Lottery Questionnaire

Subjects read a detailed description of the Indiana Pick-3 lottery (see Appendix A), and then indicated which three numbers they would play. Subjects were then presented a list of nine 3-digit numbers (three with no repeating digits, three with two repeating digits, and three with three repeating digits) and were asked to indicate which of the nine numbers they would be most likely to play.[2]

Procedure and Design

Subjects were run in small groups of 2 to 10. The study was described as being concerned with people's perceptions of lotteries. Hypothetical

[2]Subjects also responded to several questions regarding their beliefs about number selection strategies. These questions were exploratory and peripheral to the major focus of our research and hence we do not report them in detail here. We should note, however, that a majority expressed rational beliefs. For example, only 23.5% of the subjects indicated that a particular number selection strategy (i.e., always playing the same number vs. changing one's numbers) would make a difference in their chances, and 11.8% indicated that playing a number that had just won would affect their chances.

lottery questionnaires containing either the 1/10 or 10/100 lottery were randomly distributed to subjects. Subjects were instructed to read the description of the hypothetical lottery, and then answer all of the questions that followed. After completing this questionnaire, subjects then received the pick-3 lottery questionnaire. Again, subjects were instructed to read the description of the lottery, and then answer all of the questions that followed. Completion of the two questionnaires took approximately 15 minutes.

Results and Discussion

Hypothetical Lottery

Each question was analyzed separately with a 2 × 2 (Lottery Condition × Sex) analysis of variance (ANOVA). There were no significant effects for sex and this variable will not be discussed further.

The results for the lottery manipulation are presented in Table 1. Subjects responding to the 1/10 lottery perceived the likelihood of winning the lottery to be greater ($M = 4.11$) than did subjects responding to the 10/100 lottery ($M = 3.06$), $F(1, 30) = 8.03$, $p < .01$. Similarly, subjects in the 1/10 lottery condition also estimated their chances of winning the lottery to be greater ($M = 23.22\%$) than did subjects responding to the 10/100 lottery ($M = 10.25\%$), $F(1, 30) = 5.21$, $p < .05$.[3] These results, then, clearly support the operation of an anchoring and adjustment heuristic rather than a simulation heuristic. Note that this effect is not due to differences in the perceived clarity of the two lottery procedures. Subjects did not perceive the lottery procedure to be clearer for the 1/10 lottery ($M = 5.78$) than for the 10/100 lottery ($M = 5.63$), $F(1, 30) < 1$.

Lottery type did not affect the other measures. There were no reliable differences for likelihood of playing the lottery, $F(1, 30) < 1$, the amount that subjects would bet, $F(1, 30) < 1$, or the number of times the lottery would be played (assuming continued losses), $F(1, 30) = 3.61$, $p > .05$ (see Table 1).

Pick-3 Lottery

Number choices were assessed in two ways. Subjects indicated (a) which three-digit number they would play if they were to play this

[3]When these analyses are restricted to only subjects who had previously played a lottery, all results remain significant at $p < .05$.

Table 1

Summary of Mean Perceptions of Hypothetical Lottery as a Function of Lottery Condition: Experiment 1

Measure	Lottery condition		F
	1/10	10/100	
Perceived likelihoodof winning	4.11	3.06	8.03**
Estimated chances (%) of winning	23.22%	10.25%	5.21*
Perceived clarity of procedure	5.78	5.63	<1
Likelihood of playing	4.22	5.56	<1
Amount bet	2.28	2.38	<1
Number of times will play if continue to lose	8.00	25.94	3.61

*$p < .05$. **$p < .01$.

lottery (free selection), and (b) which number they would play when choosing from a predetermined list of numbers (list selection). The frequency with which numbers with zero, two, and three repeating digits were chosen is presented in Table 2.[4] Chi-square tests were conducted to examine whether these choices deviated from a random selection process. However, because of the small sample size the expected frequency for the three-repeating-digits cell was less than five. Accordingly, the two- and three-repeating-digits cells were combined for the analyses. Although in the predicted direction, the selection of numbers did not deviate significantly from chance for either the free selection of numbers, χ^2 $(1, N = 32) = 2.43, p < .12$, or the list selection, χ^2 $(1, N = 31) < 1$.[5]

Experiment 2

This experiment was conducted in an attempt to replicate and extend

[4]The reduced ns are due to some subjects not following instructions (e.g., choosing more than three numbers) or not completing these measures.

[5]For the free selection measure, the deviation from chance was marginally significant (p < .088) with a binomial test.

Table 2

Frequency of Numbers With Repeating and Nonrepeating Digits Selected in Experiment 1

Procedure	Number of repeating digits		
	0	2	3
Free selection[a]	27 (84%)	3 (9%)	2 (6%)
List selection[b]	24 (77%)	4 (13%)	3 (10%)
Expected proportion[c]	72%	27%	1%

[a]Numbers subjects indicated they would play.
[b]Numbers that subjects selected from a list.
[c]Proportion of numbers selected if numbers were randomly chosen.

the results for the anchoring and adjustment heuristic, and to test for the operation of the representativeness heuristic with a larger sample. The basic procedure was the same as in Experiment 1, but the following changes were made. First, for the hypothetical lottery we added a third condition in which the chances of winning remained the same (1 in 10) but the lottery operator chooses 100 numbers (from 1000), and thus there are 100 chances to win. In this condition the simulation heuristic should be particularly likely to occur. Also, we changed slightly the wording of each version of the hypothetical lottery in order to increase the salience of the "chances of winning" aspect. This was done by placing the sentence describing the number of numbers to be chosen earlier in the description. By making the number of chances to win more salient (for the 10/100 and 100/1000 lotteries), the likelihood that the simulation heuristic could operate was increased. Still, based on the results of Experiment 1, we expected subjects in the 1/10 lottery condition to estimate their chances of winning to be greater than subjects in the 10/100 or 100/1000 lottery conditions. Also, for all questions asking subjects to provide estimates of winning we added instructions emphasizing that subjects should try to be as accurate as possible.

Second, using a larger sample we again tested for the operation of the representativeness heuristic in the selection of lottery numbers. To test this we used the Indiana Pick-4 lottery rather than the Pick-3 lottery. This lottery is identical to the Pick-3 lottery except that four rather than three numbers are chosen.

Method

Subjects

Sixty introductory psychology students (17 males and 43 females) participated in this study. They received partial course credit for their participation. Forty (67%) subjects had played a lottery before.

Materials

The materials were identical to those used in Experiment 1 with the following exceptions. A description of the Indiana Pick-4 lottery (rather than Pick-3) was used (see Appendix B). The questions regarding this lottery remained the same.[6]

There were three versions of the hypothetical lottery, including the 1/10 and 10/100 versions used in Experiment 1 (see Appendix B). In the third version (termed the 100/1000 lottery) a player chooses one number (between 1 and 1000) that must match any of the 100 numbers selected without replacement (between 1 and 1000) in the lottery. Also, the sentence describing the number of numbers selected (1, 10, or 100) was placed earlier in the description (see Appendix B). All of the questions used in Experiment 1 were retained, and subjects were instructed to be as accurate as possible. An additional question was included asking subjects how many times they would play this lottery (regardless of outcome).

Procedure and Design

Subjects were randomly assigned to one of the three hypothetical lottery conditions, and the procedure was identical to that used in Experiment 1.

[6]Subjects also responded to the same belief questions used in Experiment 1. Only 36.7% indicated that the use of a particular selection strategy would affect their chances, and 27% indicated that playing a number that had just won would affect their chances.

Results and Discussion

Hypothetical Lottery

Responses to all questions were analyzed separately with a 3 × 2 (Lottery Condition × Sex) ANOVA. The only significant effect for sex occurred for number of times subjects indicated they would play the lottery (if they continued to lose): males indicated they would play more times ($M = 28.59$) than did females ($M = 6.84$), $F(1, 54) = 5.26$, $p < .05$.

The results for the lottery manipulation are presented in Table 3. Significant effects for lottery condition occurred for perceived likelihood of winning, $F(2, 54) = 4.11$, $p < .03$, and estimated chances of winning, $F(2, 54) = 3.11$, $p < .05$.[3] Subjects in the 1/10 lottery condition indicated the likelihood of their winning to be greater ($M = 3.95$) than did subjects in the 10/100 (M = 2.60) or 100/1000 ($M = 3.0$) lottery ($p < .05$, Newman-Keuls). Similarly, subjects in the 1/10 lottery condition estimated their chances of winning to be higher ($M = 17.16\%$) than did subjects in the 10/100 ($M = 9.0\%$) or 100/1000 ($M = 9.05\%$) lottery (Newman-Keuls tests indicated that only the 100/1000 lottery was significantly different from the 1/10 lottery at $p < .05$). The lack of a difference between the 10/100 and 100/1000 lotteries in perceived probability of winning suggests that it is the disjunctive nature of the lottery, rather than the absolute number of selections, that is important.

These results thus replicate the results of Experiment 1 and provide strong evidence for the operation of an anchoring and adjustment heuristic. This effect occurred again even though subjects were instructed to be as accurate as possible, and even though the lottery descriptions were changed to make the simulation heuristic more salient. Again this effect was not due to differences in the perceived clarity of the lottery descriptions, $F(2, 54) = 2.29$, $p > .10$ (see Table 3).

As in Experiment 1, lottery type did not have an effect on likelihood of playing the lottery, $F(2, 54) < 1$, the amount that subjects would bet, $F(2, 54) < 1$, how long they would continue playing the lottery (assuming that they continued to lose), $F(2, 54) < 1$, or how long they would play the lottery (regardless of outcome) $F(2, 54) = 1.14$, $p > .30$ (see Table 3).

Pick-4 Lottery

Subjects indicated which four-digit number they would play if they were to play the lottery (free selection), and they chose a four-digit number to play from a list (list selection). Due to the small expected frequencies for the three- and four-repeating-digit numbers, the data

Table 3

Summary of Mean Perceptions of Hypothetical Lottery as a Function of Lottery Condition: Experiment 2

Measure	Lottery condition		
	1/10	10/100	100/1000
Perceived likelihood of winning	3.95[a]	2.60[b]	3.0[b]
Estimated chances (%) of winning	17.16%[a]	9.0%[ab]	9.05%[b]
Perceived clarity of procedure	6.0	5.90	5.43
Likelihood of playing	3.79	3.45	3.76
Amount bet	2.68	3.60	3.10
Number of times will play if continue to lose	7.0	14.55	16.95
Number of times will play regardless of outcome	81.57	7.94	6.31

Note. Numbers in a row that do not have a superscript in common are significantly different at p < .05, Newman-Keuls.

were collapsed into cells with repeating digits and no repeating digits. In this analysis the selection of numbers deviated from chance for free selection, χ^2 $(1, N = 58)$ 21.77, $p < .001$.[3] As can be seen in the top half of Table 4, numbers with repeating digits were chosen more frequently, and numbers without repeating digits were chosen less frequently, than would be expected by chance. The results for the list selection measure were in the same direction (see Table 4) and were marginally significant, χ^2 $(1, N = 53) = 2.98$, $p < .10$.[4] These results are consistent with the operation of a representativeness heuristic in the selection of lottery numbers.

Experiment 3

The tests of the representativeness heuristic in Experiments 1 and 2 were somewhat inconclusive. Although number choices were in the predicted direction in both experiments (i.e., numbers without repeating digits were chosen more frequently) the results were significant in Experiment 2 but not in Experiment 1. The samples in both experiments were small (especially Experiment 1 with an n of 31) and subjects were

Table 4

Frequency of Numbers With Repeating and Nonrepeating Digits Selected in Experiment 2

Procedure	Number of repeating digits			
	0	2[a]	3	4
Free selection[b]	47 (81%)	9 (16%)	2 (3%)	0 (0%)
List selection[c]	33 (62%)	14 (26%)	3 (6%)	3 (6%)
Expected proportion[d]	50.4%	45.9%	3.6%	.1%

[a]Includes numbers with two pairs of repeating digits, as well as numbers with one pair of repeating digits.
[b]Numbers subjects indicated they would play.
[c]Numbers that subjects selected from a list.
[d]Proportion of numbers selected if numbers were randomly chosen.

making hypothetical decisions with no money at stake. To circumvent these two problems we examined the numbers chosen by actual lottery players in the Indiana Pick-3 lottery. This provided us with a very large sample of subjects who made real decisions with real money at stake.

Method

The frequency with which each possible number was played in the Indiana daily Pick-3 lottery for 15 days (July 1-July 15, 1991) was obtained from the Indiana Lottery Commission. Numbers played were then grouped into (a) numbers with no repeating digits, (b) numbers with two repeating digits, and (c) numbers with three repeating digits.[7]

[7]Numbers that were boxed (i.e., all possible combinations are played) were treated as separate numbers. Thus, if the number 375 was boxed, it was treated as six different numbers, resulting from the six different combinations. Note, however, that the wager per number is thus reduced, relative to the playing of numbers that are not boxed.

Table 5

Frequency (in thousands) of Numbers With Repeating and Nonrepeating Digits Selected in the Indiana Daily Pick-3 Lottery

	Number of repeating digits		
	0	2	3
Frequency of play	1922.8 (86%)	283.9 (12.6%)	30.3 (1.4%)
Expected proportion[a]	72%	27%	1%

[a]Proportion of numbers selected if numbers were randomly chosen.

Results and Discussion

A chi-square test was used to determine if number selection deviated significantly from chance (i.e., random selection). Consistent with Experiment 2, the selection of numbers did differ significantly from chance, χ^2 (2, N = 2237013) = 232949, $p < .001$. As can be seen in Table 5, numbers without repeating digits were played more frequently, and numbers with two repeating digits were played less frequently, than would be expected by chance. Numbers with three repeating digits, however, were not played less frequently than chance.

General Discussion

Two major findings resulted from this research. First, there was evidence for the operation of an anchoring and adjustment heuristic in perceptions of winning different lotteries. Subjects who responded to the 1/10 lottery believed their chances of winning to be greater than did subjects who responded to the 10/100 or 100/1000 lotteries. This effect occurred in both Experiment 1 and Experiment 2 (when accuracy was stressed), and it was not due to differences in the clarity of the lottery procedures. Because the 1/10 lottery was a single event, and the other lotteries were disjunctive events, this lends support to previous research demonstrating lower preferences for gambles based on disjunctive events (Bar-Hillel, 1973). Our results suggest that these preferences are a result of differences in the perceived probability of winning.

These results, then, provide support for the operation of the anchoring and adjustment heuristic in this situation rather than the simulation heuristic. How can this be reconciled with research documenting the operation of a simulation heuristic in certain situations (e.g., Miller, et al., 1989)? Note that previous research on the simulation heuristic has involved judgments about events that have happened in the past. In contrast, the present situation involved the a priori estimation of chances of winning a lottery in the future. One possible boundary condition for the simulation heuristic is that it operates only after the fact. Hence it plays a role in judgments of suspiciousness and feelings of regret regarding past outcomes, but does not play a role in the a priori judgments of future events, such as gambles. Future research should continue to pit heuristics against each other in an attempt to delimit their boundary conditions. This is especially important because there are numerous heuristics relevant for gambling that make opposing predictions. Theoretical progress in this area depends on the a priori specification of the conditions under which particular heuristics will and will not operate (Wagenaar, 1988).

Although these results are based on hypothetical lotteries, they do have implications for actual lottery play. Our subjects perceived their chances of winning to be greater for a single event lottery than for a lottery based on a disjunctive event. If the general principle holds, people should likewise perceive their chances of winning to be greater for lotteries based on conjunctive events. This is important because many lotteries (e.g., daily pick games and lotto) are conjunctive events. Future research should address this possibility.

Note, also, that the anchoring and adjustment heuristic may extend to other aspects of how lotteries are played. For example, many people play lotteries in groups, thereby allowing each participant to have a stake in more than one number. Thus, for each player the probability of winning is increased, a feature that may make this mode of lottery play attractive. However, there may be an inadequate adjustment for the reduced payoff that will occur (i.e., any winnings will have to be split between all of the participants).

Second, we found partial support for the operation of the representativeness heuristic in the lottery numbers people choose to play. According to the representativeness heuristic, numbers with repeating digits appear less random and hence should tend to be avoided. Subjects in Experiments 2 and 3 showed a tendency to pick numbers without repeating digits at a rate that deviated significantly from chance. Importantly, this effect also occurred (in Experiment 3) when the numbers chosen by actual lottery players were analyzed. Note that this bias may also occur in other lotteries. For example, in many weekly lotto games players choose six numbers between 1 and 46. We would predict, based on the representativeness heuristic, that numbers in sequence (e.g., 4, 5, 6, 7, 8, 9) would be played less frequently because they appear to be less random.

At the same time, however, the data were not entirely consistent with the representativeness heuristic. Specifically, in Experiment 3 numbers with three repeating digits were slightly overrepresented. It was not possible to determine empirically why this occurred, and hence our results should be considered as partial support for the representativeness heuristic. That is, our results suggest that people will tend to overplay numbers without repeating digits and underplay some (but not all) numbers with repeating digits.

It is best to conclude, therefore, that number selection is not exclusively determined by the representativeness heuristic. For example, people may have favorite numbers (e.g., birthdates) and use various strategies that override the representativeness heuristic. There is a similar problem when the representativeness heuristic is applied to other real-life gambling such as blackjack. The representativeness heuristic is the basis for the gamblers' fallacy, or the belief that after a series of losses the probability of a win increases. Consistent with this belief, some blackjack players will increase their wagers after a series of losses (Keren & Wagenaar, 1985). Not all players, however, will do this. Some, in fact, will demonstrate the reverse pattern and decrease their wagers when losing (a pattern that is consistent with the availability heuristic). Thus, any wagering pattern can be explained after the fact. Further empirical research is thus required to specify those conditions under which representativeness (and other heuristics) will and will not operate.

Our research does have several possible limitations. First, in Experiments 1 and 2 our subjects were college students rather than actual lottery players. However, the large majority of these students had played the lottery before, and our results were the same when the analyses were restricted to those with lottery experience. Moreover, the fact that these biases occurred with college students (who are probably more intelligent than the general public) suggests that they may be even more pronounced in the general public. A more serious limitation is that in Experiments 1 and 2 our subjects were not actually playing a lottery; if money was at stake our results may have been different. However, the fact that the same findings occurred when we analyzed number choices in a real lottery suggests (at least for the representativeness heuristic) that our laboratory results do generalize.

Like all real-world gambling, playing the lottery involves many decisions, such as whether to play, which lottery to play, which numbers to play, how much to wager, and so on. Thus, the study of lottery play offers a unique opportunity for examining the operation of decision-making heuristics and biases in real life. In particular, the data from actual lotteries can be fruitfully analyzed in this way. In addition, lottery play is probably the most common form of gambling and so it is an important topic in and of itself. Cognitive factors alone, however, will not explain how and why people play the lottery; future research on the motivational and social factors involved in lottery play is required.

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APPENDIX A

Lotteries Used in Experiment 1

Hypothetical Lottery

In this lottery there are 10 (100) balls, each with a different number between 1 and 10 (100). A player in this lottery chooses a single number between 1 and 10 (100). The lottery operator then randomly selects one ball from the 10 (10 balls from the 100). The player wins if the number selected by the player matches the number (any one of the ten numbers) selected by the operator. The payoff for correctly selecting the winning number is 10 for 1. Thus, if the player bets $1 and wins, he or she would receive $10 in return.

Pick-3 Lottery Description

Indiana offers a daily pick-3 lottery. In this lottery, the player chooses three numbers between 0 and 9. For example, a player might choose 943, 101, 333, 573, etc. When the lottery drawing takes place, three numbers between 0 and 9 are randomly selected. These numbers are selected in order. So, in order to win the player must choose the three numbers in the correct order. For example, if the player selected 985 and the numbers dran were 859 the player would not win because the correct order was not chosen.

APPENDIX B

Lotteries Used in Experiment 2

Hypothetical Lottery

In this lottery there are 10 (100) (1000) balls, each with a different number between 1 and 10 (100) (1000). One (Ten) (One hundred) ball(s) will be randomly chosen. A player in this lottery selects a single number between 1 and 10 (100) (1000). The player wins if the selected number matches the number (any of the numbers) selected by the operator. The payoff for correctly selecting the winning number is 10 for 1. Thus, if the player bets $1 and wins, he or she would receive $10 in return.

Pick-4 Lottery Description

Indiana offers a daily pick-4 lottery. In this lottery the player chooses four numbers between 0 and 9. For example, a player might choose 9432, 1015, 3333, 5736, etc. When the lottery drawing takes place, four numbers between 0 and 9 are randomly selected. These numbers are selected in order. So, in order to win the player must choose the four numbers in the correct order. For example, if the player selected 9853 and the numbers drawn were 8593 the player would not win because the correct order was not chosen.