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THE GAMBLER'S FALLACY AND GENDER

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The gambler's fallacy and gender

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Abstract

The "gambler's fallacy" is the false belief that a random event is less likely to occur if the event has occurred recently. Such beliefs are false if the onset of events is in fact independent of previous events. We study gender differences in the gambler's fallacy using data from the Danish state lottery. Our data set is unique in that we track individual players over time which allows us to investigate how men and women react with their number picking to outcomes of recent lotto drawings. We find evidence of gambler's fallacy for men but not for women. On average, men are about 1% less likely to bet on numbers drawn in the previous week than on numbers not drawn. Women do not react significantly to the previous week's drawing outcome.

JEL Codes: D03, D81, D84, J16

Keywords: lottery gambling, gender, gambler's fallacy

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Introduction

The gambler's fallacy is the false belief in a negative correlation between independent trials of a random process (Tversky and Kahneman, 1971). For example, when observing a sequence of coin tosses a player prone to the gambler's fallacy believes that "tails" is more likely than "heads" when, say, the three previous coin flips ended on "heads". This is an example of a biased belief because the flips of a fair coin are independent, i.e. heads are in fact as likely as tails independent of the previous realizations of coin flips.[3]

Evidence for the gambler's fallacy abounds and comes from a variety of data sources which all have their advantages and limitations. For example, in incentivized laboratory experiments people who are asked to generate a random sequence of binary events predict outcomes to alternate more often than a random sequence would (see Bar-Hillel and Wagenaar, 1991, and Rapoport and Budescu, 1997). Huber et al. (2010) also find behavior consistent with the gambler's fallacy in a lab experiment, as the frequency of betting on heads decreases after streaks of heads and vice versa for tails.

Evidence from the experimental laboratory is highly informative because of the tight control the lab setting allows. But such evidence is sometimes criticized as artificial and lacking external validity. Therefore, researchers have turned to survey representative samples and to study gambling in natural settings like state lotteries and casinos. In a representative survey Dohmen et al. (2009) present respondents in a questionnaire with a hypothetical series of 8 coin tosses that end with 3 tails and ask respondents to indicate

[3] Tversky and Kahneman (1971) suggest that the gambler's fallacy results from the representativeness heuristic: many people believe that small samples should "look like" large samples (in which the proportion of heads and tails will be very close to 50:50) and that a sample that happens to deviate from this proportion should quickly revert to that proportion.

the probability of the next coin flip. The authors find that, overall, more than 20% of the respondents believe that tails has less than a 50% chance to come out in the next coin toss. Whereas such surveys have the advantage of being representative, they have the disadvantage of lacking incentives. State lotteries and casinos are naturally occurring environments which at same time provide high incentives and relatively tight control on the data generating process. Sequences of lotto drawings are excellent examples of truly independent random processes and the nature of randomness is intuitively accessible since it is based on physical devices (the movement of balls). A limitation of such studies compared to representative surveys is selective participation. Only some people choose to play roulette or participate in lotteries, and these people may differ in relevant characteristics from the general population. Clotfelder and Cook (1993) and Terrell (1994) document the gambler's fallacy among lottery players, and Croson and Sundali (2005) and Sundali and Croson (2006) among roulette players. However, none of these studies have been able to document gender differences in the gambler's fallacy.

We study gender differences in the gambler's fallacy using data from state lottery gambling over the internet. Thus, we use data from a tightly controlled yet natural setting in which participants face substantial incentives. We are, to the best of our knowledge, the first to show gender differences in the gambler's fallacy in such a context. While our data also potentially suffers from selective participation, it has an important advantage over the lottery data used in previous studies (Clotfelder and Cook, 1993, Terrell, 1994): our data allows us to track individuals over time because each player is identified by a unique identifying number. We can thus not only identify the gender of players but also the numbers they pick in consecutive weeks. This unique aspect of our data allows us to

investigate how gamblers react with their number picking to recent draws, and how such a reaction is related to the gambler's gender. Hence, we believe that this new source of data can offer an important additional perspective on the gambler's fallacy.

We find, among other interesting gender differences, that men but not women are less likely to pick lotto numbers that happened to be drawn in the previous week. This finding is novel and, in view of the scarce and ambiguous available evidence, perhaps also surprising. For example, Dohmen et al. (2009) find that women are more likely than men to have biased beliefs about the outcomes of a hypothetical coin toss. Also, experimental evidence on Bayesian updating shows that men are better Bayesian probability updaters than women (Charness and Levin, 2005).

Our paper also adds to the literature documenting gender differences in gambling along various dimensions. This literature shows that men gamble more than women. They play more frequently and spend more money when they play. For example, Farrell and Walker (1999) and Kearney (2005) show that men spend much more money on lottery tickets than women in the UK and the US, and Wärneryd (1996) finds that men play lotto more frequently in a representative survey in the Netherlands. Men are also more likely to be problem gamblers than women (see Johansson et al., 2009, for an overview), and men have been found to be less risk averse and more (over)confident in laboratory experiments than women (see, for example, Eckel and Grossman, 2008, and Niederle and Vesterlund, 2007; for an overview of the literature, see Croson and Gneezy, 2009).

The paper proceeds as follows. Section 2 describes the data. Section 3 presents the results and section 4 concludes.

The data

We use data from the national lotto in Denmark which is organized by a state monopoly. Every Saturday, 7 balls are drawn from an urn containing 36 balls numbered from 1 to 36. The drawings are aired on state TV. Residents in Denmark can gamble by selecting combinations of 7 numbers. They win prize money if at least four numbers correspond to the ones drawn in that week. The price of a lotto ticket is about EUR 0.40 (DKK 3) and each ticket represents one combination.[4] The overall payout rate is set to 45% by government regulation and the remainder of the revenues mostly goes for "good causes" and to a small extent to the general government budget. Lotto has a pari-mutuel structure as the amounts of prize money are fixed per prize category and the prize money per category is shared among the winners in that category. One quarter of all payoffs are reserved for the jackpot (7 correct numbers), and there are four graded prizes for having selected fewer correct numbers. If nobody wins the jackpot, it is rolled over to the next week. In our data set, the average jackpot was about EUR 534'000 (4 million DKK), and the highest jackpot was 1.4 million EUR (10.2 million DKK). Prizes above DKK 200 are subject to a special tax of 15% but are otherwise exempt from income tax.[5]

[4] All numbers in this section refer to the period covered in our data (the second half of 2005).
[5] The prize structure has been modified after 2005.

We investigate lotto numbers picked by players over the internet in the last 28 weeks of the year 2005 (from week 25 to week 52). The data has been provided to us directly by Dansk Spil, the agency organizing the Danish lotto. Lotto numbers can be picked in various ways in Denmark. Traditionally, players manually select 7 (out of 36) numbers on each ticket they buy. Other ways to play are "Quicklotto" where all numbers are selected randomly by the lotto agency, and "Systemlotto" where players select at least 8 numbers manually and let the lotto agency choose combinations from these numbers randomly. There are several ways ("systems") to play Systemlotto which differ by how many numbers are picked and how many tickets are generated from these numbers (see appendix for details).

We use data from Systemlotto (rather than traditional manual selection) in our analysis because we are interested in how picking lotto numbers depends on whether that number has been drawn previously. In Systemlotto players select numbers rather than combinations of numbers as in traditional manual selection.[6] With Systemlotto, players choose fewer unique numbers than traditional players which suggests that Systemlotto players are more likely to believe that a particular number is going to win. Players who select numbers in the traditional way typically buy several tickets that each have a different combination of numbers. Often, combinations are selected that yield specific patterns on the play grid, such as multiples of 7 or combinations that "look random" thereby avoiding adjacent numbers (see Simon, 1999). To illustrate, Systemlotto players pick less than half among the 36 available numbers (14 numbers in an average week, 8 in

[6] Our data set contains all number choices made by the players and we use these data in all analyses reported below. Unfortunately, we do not have full information about winners and winning prizes because for many cases we do not know which combinations from the numbers are in the end (randomly) chosen by the lotto agency.

a modal week), while players who use traditional manual selection pick many more available numbers (29 in an average week, 32 in a modal week). Thus, given the nature of number picking under traditional manual selection, it is relatively unlikely that these players are guided by the outcomes of previous weeks' drawing in selecting their numbers, making these data much less suited than Systemlotto data to examine the gambler's fallacy.

Two aspects of the data allow us to investigate gender differences in the gambler's fallacy. First, all players in our dataset are identified by a unique ID-number, which allows us to track the choices of players over time. In particular, we analyze how players react with respect to the numbers they pick to the numbers that have been drawn (drawn numbers are public information and can be downloaded from the website of the lotto agency). Of course, such a reaction is only defined for players who have played in (at least) two consecutive weeks. Second, we have data on the gambler's gender which allows us to investigate gender differences in how players react to draws.

Table 1 provides descriptive statistics on the number of players, their age, the number of tickets bought by the gender of the player, and the number of weeks of play. In total, 189'531 persons have played lotto over the internet at least once in the second half of 2005, and the majority selects numbers manually (100'386 persons). About a quarter (25'807 persons) of these use Systemlotto to gamble. Of the 25'807 Systemlotto players in our dataset, 17'318 players have at least two consecutive observations such that it is possible to measure how they react to the previous week's outcome. One commonly observed fact in how players pick lotto numbers is that most players stick to a given set of numbers irrespective of which numbers have been drawn (see Simon, 1999, for a

discussion).[7] In our sample, about two thirds (11'214 players) always select the same set of numbers, and 6'806 players choose a different number at least once in two consecutive weeks.

Table 1: Descriptive statistics on internet lottery players who manually select numbers

	Total	**Male**	**Female**
# Players	100'386	73'110 (72.8%)	27'276 (27.2%)
Average (median) age	42.6 (41)	42.5 (41)	42.8 (42)
Average (median) # tickets by week	17.0 (10)	18.5 (10)	12.9 (10)
Average (median) weeks of play	16.0 (18)	15.5 (16)	17.4 (21)
# Systemlotto players	25'807	21'207 (82.2%)	4'600 (17.8%)
Average (median) age	45.0 (45)	44.9 (44)	45.1 (45)
Average (median) # tickets by week	37.6 (24)	39.8 (24)	27.4 (17)
Average (median) weeks of play	11.2 (7)	11.0 (6)	11.9 (8)
# Systemlotto players with at least two consecutive observations	17'318	14'099 (84.8%)	3'219 (15.2%)
Average (median) age	46.2 (46)	46.1 (46)	46.2 (46)
Average (median) # tickets by week	35.4 (24)	37.5 (24)	26.2 (16)
Average (median) weeks of play	15.9 (16)	15.8 (16)	16.3 (17)

Table 1 shows that Systemlotto is more popular among men than women, and that men spend more money on Systemlotto gambling in the sense that they buy more tickets, on average. In fact, although women typically play lotto in more weeks than men, selecting lotto numbers over the internet is more popular among male than female players (73% vs. 27%, see first row). Clearly, this gender distribution is neither representative for

[7] In Denmark, empirical regularities regarding gambling and gender differences in gambling are similar to those in other countries (see Lyk-Jensen, 2010).

the pool of lotto players in Denmark nor for the Danish population in general.[8] Because it is unlikely that Danish men have better access to internet per se, the overrepresentation of men suggests that they use the internet more for gambling than women. Moreover, Table 1 shows that among the internet players who play Systemlotto the overrepresentation of men is even more pronounced than among all internet players who manually select numbers (82% male vs. 18% female). From those who have at least two consecutive observations 85% are male and 15% are female. Finally, Table 1 shows that Systemlotto players buy on average about 20 tickets by week more compared to all players who select numbers manually (37.6 vs. 17.0 tickets, respectively) and that male players buy more tickets than female players. Men buy about 11 tickets or spend about 4 EUR per week more on Systemlotto than female players (see next-to-last row of Table 1).[9]

Thus, there clearly is selection into (frequent) Systemlotto play by gender, meaning that one needs to be careful with extrapolating our findings to the population at large. Since we do not have data on number picking by the general population (and such data does not exist because there is already selection into lotto gambling in the first place) and since we do not have detailed information on the socio-economic characteristics of the players, we can only speculate on how selection impacts on our findings. One possibility is that people prone to the gambler's fallacy are more likely to gamble, to gamble more frequently, and spend more money, if they gamble. In this case, the estimate from our sample would overestimate the extent of gambler's fallacy in the overall population.

[8] According to the Danish lotto agency, 52% of all lotto players are male and 48% are female (percentages refer to all lotto players, i.e. including lotto players who buy their tickets at vending booths).

[9] Players who use the "Quicklotto" device to select numbers buy on average 17.3 tickets per week, and play during 10.2 weeks. As in Systemlotto, male players buy more tickets than female players in Quicklotto (18.2 vs. 14.5 tickets per week).

However, in this case, gender differences would also be obfuscated because there is no reason to expect that selection into Systemlotto would be different for men and women. As a consequence, any gender difference found in our sample is a lower bound for gender differences in the gambler's fallacy present in the population. Unfortunately, available studies investigating selection into gambling do not provide a clear indication which way selection may affect our estimates.[10]

Table 1 suggests that there is no pronounced selection by gender and age into our sample. The table shows that there are no pronounced age differences between male and female Systemlotto players in the sample analyzed below (i.e. those with at least two consecutive observations) but they are about one year older than the average Systemlotto player, and more than three years older than the average manually selecting player.

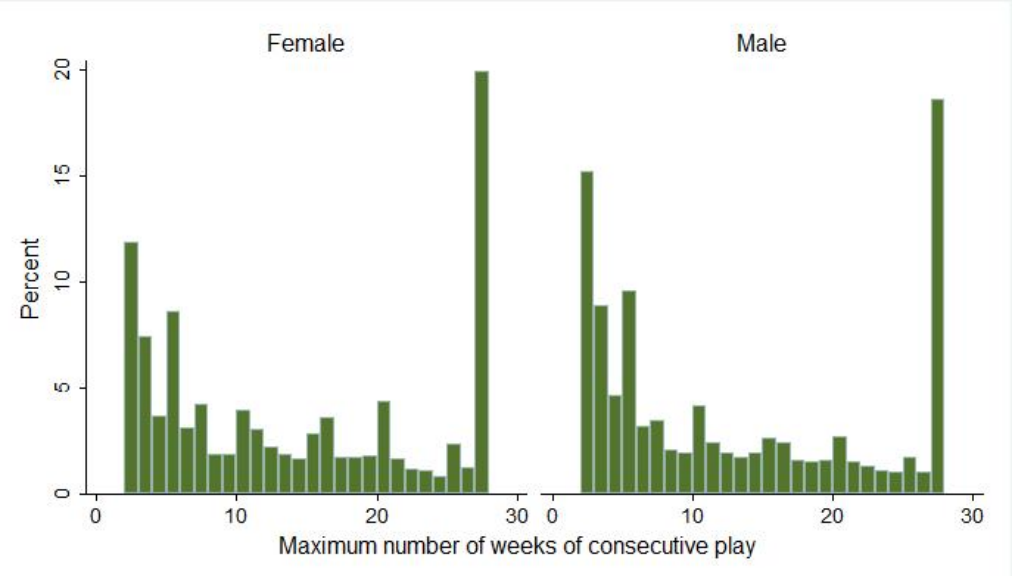
Finally, we provide some information about the distribution of consecutive weeks in which players gamble through Systemlotto. Recall that our focus is on how number picking reacts to numbers drawn, and that such a reaction is defined only for players who play at least in two consecutive weeks. Among all Systemlotto players analyzed below, about two thirds have at least two consecutive observations (see Table 1). Figure 1 depicts the distribution of the maximum number of consecutive weeks of Systemlotto play by gender given that they play at least in two consecutive weeks.[11] The figure shows that, for both men and women, the mode is to gamble in all 28 weeks. The figure also shows that the majority of players gambles during 5 consecutive weeks or less. This

[10] Griffiths and Wood (2001), Rogers and Webley (2001) and Delfabbro et al. (2006) suggest that problem gamblers are more prone to the gambler's fallacy than non-problem gamblers, whereas Källmén et al. (2008) and Lyk-Jensen (2010) do not find a difference.

[11] Some players play often but skip a week now and then. For example, for a player who gambles in four consecutive weeks, another time in six consecutive weeks, and then again in two consecutive weeks, the maximum number of consecutive weeks is six. This number is depicted in Figure 1.

pattern is most pronounced for men: 38 percent of the male and 32 percent of the female players gambles during 5 or fewer consecutive weeks. If we regress the maximum number of consecutive weeks observed on gender and age, both turn out to be statistically significant ($p < 0.001$): men play in fewer consecutive weeks (about 1 week less) than women, and the relation with age is positive (older players play more weeks in a row than young players).

Figure 1: Distribution of maximum number of weeks of consecutive play



Notes: The figure shows the distribution of the maximum number of consecutive week observations by gender. Each data points represents a player (n = 17'318 Systemlotto players who play in at least 2 consecutive weeks).

Data analysis

This section shows that in the sample of Systemlotto players, men are prone to gambler's fallacy whereas women are not. We find that the numbers that happen to be drawn by the lotto agency in the previous week are, on average, systematically avoided in the current week by men but not by women.

We estimate the probability that a particular number is chosen by a player in the current week as a function of the draw in the previous week plus other factors, including gender. Since lotto numbers in Danish lotto are drawn independently each week, the draws in our sample are uncorrelated and the numbers drawn occur as expected.[12] The dependent variable Bet in our regressions is a binary variable that measures for each player, each lotto number, and each week of play whether the player has bet on the number in that week. The variable Bet is equal to one if he or she has bet on the number and equal to zero if not. We use three independent variables and interactions between them to investigate gender differences in the gambler's fallacy. Drawn(-1) is a binary variable that equals one if a number was drawn in the previous week, and zero otherwise. Male is a dummy indicating the player's gender, and Bet(-1) is the lagged dependent variable indicating whether a player has bet on the corresponding number in the previous week.

Including Bet(-1) in the regression serves as a control for the baseline-popularity of particular numbers. In fact, some numbers are particularly popular in general (e.g. low

[12] The outcomes of subsequent draws are not significantly correlated. A probit regression gives a p-value of 0.505.

numbers are generally more popular than high numbers[13]), and some numbers are popular with particular players over time (e.g. a player's idiosyncratic "lucky numbers"). However, we do not find evidence indicating that particular numbers are generally more popular with men than women.[14] In any case, we are not interested in gender differences in number preferences *per se*, but rather in how male and female players *react* to the previous week's drawings.

As explained below, specification (1) provides evidence that men in our sample are prone to the gambler's fallacy while women are not. We find that men are about 1 percent less likely to pick numbers drawn in the previous week than numbers not drawn. Specification (2) shows that this significant relation for men originates from the fact that men move away from numbers that happen to be drawn rather than abstaining to start selecting such numbers.

Column (1) of Table 2 shows that men are prone to the gambler's fallacy while women are not. This conclusion follows from the estimated coefficients on Male x Drawn(-1) and on Drawn(-1). The coefficient on the variable Drawn(-1) is not significant. This indicates that whether a number was drawn in the previous week does not affect women's number selection in the current week. The interaction Male x Drawn(-1) has a statistically significant coefficient of -0.9 percent. This means that men

[13] For example, the lowest 5 numbers (1 to 5) are picked more than 30% more often than the highest 5 numbers (32 to 36).

[14] The baseline-popularity of numbers is similar for men and women. In fact, we find that across the sample period, distributions of bets across lotto numbers for men and women are positively and significantly correlated ($r = .95$). Moreover, the results obtained in the regressions reported in Table 2 are not due to coincidental correlations between distributions of bets across numbers and their drawing frequency: the correlation between the distribution of bets across numbers and the drawing frequency of numbers is -.10 for men and -.13 for women (both not significant, $p > 0.4$).

are 1.1% (= -0.009-0.002) less likely to bet on a number that was drawn by the lotto agency in the previous week than on a number not drawn.[15]

Table 2: Regression results on gender and the gambler's fallacy

	Specification (1)		**Specification (2)**	
Dependent Var. = Bet	Marginal effect	*p*-value	Marginal effect	*p*-value
Male	0.085	< 0.001	0.084	< 0.001
Drawn(-1)	-0.002	0.528	-0.002	0.564
Male x Drawn(-1)	-0.009	0.002	-0.004	0.186
Bet(-1)	0.952	< 0.001	0.952	< 0.001
Male x Bet(-1)	-0.146	< 0.001	-0.144	< 0.001
Drawn(-1) x Bet(-1)			0.000	0.972
Male x Drawn(-1) x Bet(-1)			-0.011	0.005
Observed Prob.	0.370		0.370	
Predicted Prob.	0.277		0.277	
Pseudo R-squared	0.77		0.77	
Number of players	17'318		17'318	
Number of data points	8'525'016		8'525'016	

Notes: The table reports results (marginal effects and *p*-values) from probit regressions based on a pooled panel data set of players and weeks in the second half of 2005, including time (week) dummies. The dependent variable Bet is equal to one for a player *i,* lotto number *j*, week *t* if the player has selected the corresponding lotto number in the corresponding week, and equal to zero otherwise.

Column (1) of Table 2 also reveals two other interesting gender differences. First, men are 8.5% more likely than women to choose a number per se (see coefficient on Male), which implies that men bet on more lotto numbers than women do. This is

[15] The qualitative results do not depend on the number of consecutive weeks that players play lotto. For example, the same qualitative results hold for players who only play in maximum two consecutive weeks as for those who play in all 28 weeks.

because men buy more tickets than women. Second, men are 14.6% less likely than women to select the same number as in the previous week. The coefficient on Male x Bet(-1) indicates that men are less persistent in their number selection than women, and thus tend to change the numbers they bet on more frequently from one week to the other than women do.

Column (2) shows that the gambler's fallacy observed among men is caused by male players moving away from numbers drawn in the previous week, rather than by male players staying away from these numbers. That is, compared to the baseline probabilities, men are significantly less likely to pick a number again (i.e. a number they have chosen in the previous week) if it happened to be drawn, but they are not more likely not to start picking a number (i.e. a number they did not choose in the previous week) given that it has been drawn. Column (2) shows the results for a specification of the regression that includes two additional interaction terms: the interaction Drawn(-1) x Bet(-1), and the interaction Male x Drawn(-1) x Bet(-1). Including these terms allows us to distinguish between (gender differences in) staying away from numbers drawn in the previous week and moving away from numbers drawn in the previous week. The coefficient Drawn(-1) x Bet(-1) measures whether the extent to which women switch numbers (e.g. moving away from numbers drawn in the previous week) is influenced by the outcome of the previous week's drawing. The insignificant coefficient on this interaction term suggests that women are not influenced by the previous week's drawing. Thus, they are as likely to bet again on numbers drawn as on numbers not drawn. The coefficient on Male x Drawn(-1) x Bet(-1) shows that men are less likely to bet *again* on a drawn number. Particularly, they are 1.7% (= -0.002-0.004-0.011) less likely to bet again on numbers

drawn in the previous week than to bet on numbers not drawn. The coefficient Male x Drawn(-1) is insignificant in specification (2) but was significant in specification (1). Male x Drawn(-1) is insignificant because of the inclusion of the term Male x Drawn(-1) x Bet(-1) in specification (2), showing that the gambler's fallacy observed in men is indeed driven by men moving away rather than staying away from numbers drawn in the previous week.

Concluding remarks

We document gender differences in how Danish lotto players respond to the previous week's lotto drawing. We use data from Systemlotto played over the internet and find that men are significantly less likely to bet again on numbers drawn in the previous week than on numbers not drawn. Women do not change their number choices as a function of the previous week's drawing outcomes. Thus, in this sample, men are on average prone to the gambler's fallacy and women are not. The effect is driven by men moving away from numbers that they selected in the previous week, rather than staying away from numbers that they did not select in the previous week.

Biases in how players pick lotto numbers are potentially costly because the pari-mutuel structure of lotto prizes implies that coordinated movements reduce the probability of being the only winner (see also Jørgensen et al., 2011). While this means that the gambler's fallacy is potentially costly, it is perhaps not the most costly type of fallacy. For example, selecting certain patterned combinations (e.g. numbers on the same row on the ticket or equally spread numbers like 1, 6, 11, 16, 21, 26, 31) is popular and therefore likely to be more costly. Simon (1999) shows that the 1% most popular

combinations account for 10% of tickets sold in the UK state lottery (compared to 2.5% under random selection), and that choosing such a popular combination reduces the expected return to 18% while picking an unpopular combination yields an expected return of 87%.

Although our data come from state lotteries that have a particularly transparent stochastic nature, the gambler's fallacy may also appear in contexts when the random process is less transparent. In fact, Kumar (2009) shows that state lotteries and lottery-type stocks (low-priced stocks with high idiosyncratic volatility and skewness) attract the same type of individuals. Interestingly, he finds that men are more likely to invest in lottery-type stocks than women. This result resonates well with our finding that men are prone to the gambler's fallacy in lottery play but women are not. Taken together, the studies suggest that gender differences in the gambler's fallacy may be correlated with gender differences in preferences for lottery-type stocks. Given the limited data available, we think that investigating whether and how (gender differences in) the gambler's fallacy are related to investment choices is a promising field for further research.

References

Bar-Hillel, M. and Wagenaar, W. (1991). The perception of randomness. *Advances in Applied Mathematics*, 12:428–454.

Charness, G. and Levin, D. (2005). When optimal choices feel wrong: A laboratory study of Bayesian updating, complexity, and affect. *American Economic Review*, 95:1300–1309.

Clotfelder, C. and Cook, P. (1993). The "gambler's fallacy" in lottery play. *Management Science*, 39:1521–1525.

Croson, R. and Gneezy, U. (2009). Gender differences in preferences. *Journal of Economic Literature*, 47:448–474.

Croson, R. and Sundali, J. (2005). The gambler's fallacy and the hot hand: Empirical data from casinos. *Journal of Risk and Uncertainty*, 30:195–209.

Delfabbro, P., Lahn, J., and Grabosky, P. (2006). It's not what you know, but how you use it: Statistical knowledge and adolescent problem gambling. *Journal of Gambling Studies*, 22:179–193.

Dohmen, T., Falk, A., Huffman, D., Marklein, F., and Sunde, U. (2009). Biased probability judgment. Evidence of incidence and relationship to economic outcomes from a representative sample. *Journal of Economic Behavior & Organization*, 72:903–915.

Eckel, C. and Grossman, P. (2008). Forecasting risk attitudes: An experimental study using actual and forecast gamble choices. *Journal of Economic Behavior & Organization*, 68:1–17.

Farrell, L. and Walker, I. (1999). The welfare effects of lotto: evidence from the UK. *Journal of Public Economics*, 72:99–120.

Griffiths, M. and Wood, R. (2001). The psychology of lottery gambling. *International Gambling Studies*, 1:27–45.

Huber, J., Kirchler, M., and Stöckl, T. (2010). The hot hand belief and the gambler's fallacy in investment decisions under risk. *Theory and Decision*, 68: 445-462.

Johansson, A., Grant, J. E., Kim, S. W., Odlaug, B. L., and Götestam, K. (2009). Risk factors for problematic gambling: A critical literature review. *Journal of Gambling Studies*, 25:67–92.

Jørgensen, C., Suetens, S., and Tyran, J.-R. (2011~~0~~). Predicting lotto numbers. Mimeo.

Källmén, H., Andersson, P., and Andren, A. (2008). Are irrational beliefs and depressive mood more common among problem gamblers than non-gamblers? A survey study of Swedish problem gamblers and controls. *Journal of Gambling Studies*, 24:441–450.

Kearney, M. (2005). State lotteries and consumer behavior. *Journal of Public Economics*, 89:2269–2299.

Kumar, A. (2009). Who gambles in the stock market? *Journal of Finance*, 64:1889–1933.

Lyk-Jensen, S. (2010). New evidence from the grey area: Danish results for at-risk gambling. *Journal of Gambling Studies*, 26:forthcoming.

Niederle, M. and Vesterlund, L. (2007). Do women shy away from competition? Do men compete too much? *Quarterly Journal of Economics*, 122:1067–1101.

Rapoport, A. and Budescu, D. (1997). Randomization in individual choice behavior. *Psychological Review*, 104:603–617.

Rogers, P. and Webley, P. (2001). "It could be us!": Cognitive and social psychological factors in UK national lottery play. *Applied Psychology*, 50:181–199.

Simon, J. (1999). An analysis of the distribution of combinations chosen by UK national lottery players. *Journal of Risk and Uncertainty*, 17:243–276.

Sundali, J. and Croson, R. (2006). Biases in casino betting: The hot hand and the gambler's fallacy. *Judgment and Decision Making*, 1:1–12.

Terrell, D. (1994). A test of the gambler's fallacy: Evidence from pari-mutuel games. *Journal of Risk and Uncertainty*, 8:309–317.

Tversky, A. and Kahneman, D. (1971). Belief in the law of small numbers. *Psychological Bulletin*, 76:105–110.

Wärneryd, K. (1996). Risk attitudes and risky behavior. *Journal of Economic Psychology*, 17:749–770.

Appendix: Overview of the systems within Systemlotto

Type of system	# Chosen numbers in set	# Tickets/combinations generated
M	8	8
M	9	36
M	10	120
M	11	330
M	12	792
R	10	8
R	10	30
R	11	20
R	11	34
R	12	12
R	12	24
R	12	48
R	13	18
R	13	66
R	14	48
R	14	132
R	15	24
R	15	69
R	16	32
R	16	109
R	16	240
R	17	272
R	18	82
R	19	338
R	20	450
R	20	1040
R	21	198
R	23	345
R	24	455
R	25	600
C	17	17
C	18	33
C	19	52
C	20	20
C	20	80
C	22	60
C	24	24
C	24	120
C	25	100
C	25	200
C	28	194
C	30	268
C	31	155

Notes: M ("mathematical") systems comprise all combinations of the chosen numbers, whereas R ("reduced") and C ("chance") systems generate a subset of combinations of the chosen numbers.