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The Bounce-Back Effect: Checkmating Competitors with the Cold Hand

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ABSTRACT

Purpose: The paper investigates the effect of winning performance streaks (the hot hand) and losing performance streaks (the cold hand) on future performance. Performance streaks have many implications in business settings, such as selecting stocks, hedge fund performance, employee performance, introducing new products, and business strategy. **Design/methodology/approach:** The paper empirically analyzes the effects of performance steaks. It uses data from world blitz chess championships.

Findings: Contrary to some studies in competitive sports, the empirical analysis supports neither the hot hand nor the cold hand hypothesis. Instead, a new effect is discovered; performance increases following a loss. We term this effect to be the bounce-back effect.

Research limitation/implications: Future research may conduct field experiments to investigate which business environments are likely to generate this effect. Similar to other studies on performance streaks, the analysis does not control for motivation. Future research may also analyze the role of motivation for performance.

Originality/value: The paper identifies a new effect previously not investigated in the literature. In addition, the paper contributes to this literature by looking into competitive blitz chess, where psychological factors are more important than physiological factors. If the bounce-back effect holds more generally in other settings, it might have implications for predicting the performance of employees in competitive business environments.

Keywords: Performance Streaks, Bounce-back Effect

I. Introduction

The effect of performance streaks on future performance has fascinated behavioral economics for decades. While performance streaks are mostly discussed in sports, they have many implications in business (selecting stocks, hedge fund performance, employee performance, introducing new products, business strategy, etc.). With a few exceptions where researchers looked into performance streaks of mutual funds in terms of excess returns (Hendricks et al. 1993; Kosowski et al. 2006; Mauboussin and Arbesman 2011), previous research mostly uses data from competitive sports with winning performance streaks known as the hot hand phenomenon and losing performance streaks known as the cold hand phenomenon. Generally, sports data is used due to fan interest as well as interest in sports betting, and it readily lends itself to econometric analysis (Lee and Smith 2002; Kochman et al. 2017; Lyócsa and Výrost 2018). Using sports data creates

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a controlled experiment, which may not be easily implemented in business settings. Surprisingly, the effect of performance streaks has not been investigated in chess by researchers, which this paper remedies. Furthermore, the decision-making process in chess, rather than in traditional sports, is more closely related to the decision-making in business because sports emphasize physical strength and physical skills, whereas chess emphasizes cognitive skills. This paper finds neither a hot hand nor a cold hand in chess. Instead, it finds a new effect, which this paper calls "the bounce-back effect," since a loss appears to provide more of an incentive to win the next game.

There is a link between chess and business. Plaving chess creates some positive externalities, which can help form judgment and decision-making, which are the hallmarks of behavioral economics. According to Chess.com, some of the benefits include the teaching of consequences, how to win and lose, developing logic and problem-solving skills, and pattern recognition.¹⁾ As noted in Harvard Business Review article, games can improve the strategic thinking skills of business managers (Reeves and Wittenburg 2015). Judgment and strategic decision-making skills in chess are closely related to cognitive skills necessary in business, economics, politics, social interactions, and everyday life decisions (Kasparov 2008). Bob Rice, a managing partner of Tangent Capital and Bloomberg Television's alternative investment editor, highlights that chess mirrors the business world. His book provides specific examples and case studies of how chess strategies can be applied in business (Rice 2008). Unsurprisingly, some business strategy books illustrate chess pieces on their covers (David 2021; Gamble et al. 2018; David et al. 2019).

When studying performance streaks using data from traditional sports, one of the drawbacks is that it is hard to differentiate between psychological and physiological factors affecting players' performance. Since chess is a game of intellect and not brawn, chess controls for the physiological factors, which more easily permits the focus to be on incentives and decision-making. Another drawback is that it is hard to control for opposing teams or opposing player(s)' defensive physical responses when analyzing sports data.²) Chess also removes this hurdle. An indicator of strength and performance for chess players is the Elo rating system.

The Elo rating system has been adopted by the International Chess Federation (FIDE) and national chess federations such as the United States Chess Federation. Each competitive chess player is assigned a rating that describes the player's strength. Elo ratings vary from 0 to 3000 (Glickman and Jones 1999). While novice players have ratings under 1200, international masters and grandmasters are rated above 2400 (Elo 1986). The difference in players' Elo ratings is a good predictor of performance, and it is widely used to detect above-normal and below-normal performances. Therefore, the players' rating differences are used to detect unusual player performances.

To understand how the effects of performance streaks may influence economic decision-making situations, one needs to look into an activity where the role of psychological/cognitive factors is more important than the role of physiological factors. Chess most certainly fits this description. The data in this paper is gathered from world blitz championship tournaments. World blitz chess championships are exciting events for chess aficionados due to the tournaments' fast pace. While each chess player usually has two hours for the first forty moves in a regular chess tournament, the time control for the blitz tournament is three minutes per player per game with two seconds of time added after each move.3) The whole blitz tournament is played within two days, compared to regular/classic chess tournaments, which can last up to several weeks. Blitz chess championships are appropriate for our study because the shorter time between the matches

For more information on the benefits of chess, please refer to the following website: https://www.chess.com/article/view/benef its-of-hess#:~:text=Chess%20helps%20develop%20problem%2 Dsolving,and%20minuses%20of%20your%20choices.

Performance streaks have been analyzed in single-player sports such as tennis, table tennis, swimming, etc., but in all these sports, there is still a physicality involved.

FIDE. Regulations for the FIDE Open World Rapid & Blitz Championships 2023. Available at https://handbook.fide.com/fil es/handbook/wrbc_regulations_2023_open.pdf, accessed August 4, 2022.

minimizes the effects of other factors on player performance such as prolonged additional coaching opportunities, mental fatigue, or potential loss of momentum caused by long lapses in play, mind games, i.e., psychological tactics to distract opponent, etc. In addition, many more games are played daily in blitz chess competitions due to shorter time controls as each player may play up to twenty-one games in an open world blitz chess championship.

This paper finds that having a winning streak does not improve performance and having a losing streak does not decrease performance. Instead, a new effect, which has not yet been identified in the empirical behavioral economics literature, has been found. This paper finds that a player's performance increases, by a small margin, following a loss, which is referred to as the bounce-back effect. The effect is so named since a loss provides a boost or an incentive for the player to perform better in the next game and hence, "bounces back" after a loss.⁴⁾ The ability to mentally rebound from a loss or bad news has important implications in the field of behavioral economics since it can lead to more favorable economic outcomes for the individual and society at large.

Regarding the organization of this paper, Section 2 summarizes the previous literature on the topic, Section 3 presents the data, Section 4 presents and analyzes the empirical results, and Section 5 concludes.

II. Literature Review

A brief literature survey of performance streaks in various sports, such as American football, baseball, basketball, bowling, darts, golf, table tennis, tennis, swimming, soccer (football), and volleyball, is offered in the Appendix 1. Some of the literature finds very little or no evidence supporting the existence of the hot hand in sports (Gilovich et al. 1985; Tversky and Gilovich 1989; Stins et al. 2018). Alternatively, some studies do confirm the existence of the hot hand in sports data (Taylor and Demick 1994; Gilden and Wilson 1995; Abrevaya 2002; Green and Zwiebel 2017). In the finance literature, performance streaks of mutual funds are attributed either to luck, skill, or a combination of luck and skill (Kosowski et al. 2006; Hendricks et al. 1993; Mauboussin and Arbesman 2011).⁵⁾

Furthermore, some researchers argue that the hot hand exists, but it is masked by only looking at short samples rather than at longer samples (Livingston 2012; Waggoner et al. 2014). Others argue that the studies, which find no evidence of the hot hand in sports, fail to properly account for offensive and defensive responses when players or teams experience performance streaks or that the framing of the hot hand analysis changes the results (Shea 2014; Raab and MacMahon 2015).

Regarding the cold hand phenomenon, Arkes (2016) finds a cold hand in golf while Jordet, Hartman, and Vuijk (2011) find one in soccer, and Taylor and Demick (1994) find that losing players have a higher probability of a negative outcome.

There is also a regression to the mean effect in the literature, which refers to a player's uncharacteristically good or bad performances that ultimately revert to their mean performance. Attali (2013) and Shea (2014) find some evidence for the regression to the mean effect concerning basketball data as does Abrevaya (2002) concerning bowling in the long run.

Some of the other research into winning performance streaks is mixed. For instance, Malueg and Yates (2010) find that the second set's winner in a three-set tennis match has a higher probability of winning the third set. Den Hartigh and Gernigon's (2018) findings are mixed for a cold hand. They find that calling a time-out can diminish a winning streak, and it can help to reverse a losing streak as well.

⁴⁾ The regression to the mean effect refers to a player's extraordinary performance reverting back to their average performance (Abrevaya 2002; Barnett et al. 2005), which is different from the bounceback effect. The bounce-back effect refers to a one-time boost after a loss. It should be noted that the Gambler's Fallacy refers to the expectation of an opposite of an event occurring if said event occurs more frequently than it should (Huber et al. 2010).

⁵⁾ According to Phung and Khuong (2017), personality traits can also affect investment decisions.

III. Data

The data is obtained from Chess-Results.com website.⁶⁾ In particular, the match results from the 2014 to 2018 Open World Blitz Chess Championship and Women's World Blitz Chess Championship tournaments, as organized by FIDE, are analyzed.⁷⁾ The open chess tournaments are open to both men and women, while women's chess tournaments are open only to women. Only a few women participate in the open tournament at the highest level of play, even though the FIDE does not directly restrict any chess tournaments to be for men only.⁸⁾

The data sample precedes a sudden rise in popularity of chess, especially online chess, which has occurred due to the Covid-19 pandemic and the airing of Netflix's "The Queen's Gambit."⁹ Having new players attracted to chess further ensures the longevity of this ancient sport, but the lack of experience in chess players would add some noise to the dataset, which could skew the findings. Hence, the dataset is limited to the 2014 to 2018 Open World Blitz Championship and Women's World Blitz Chess Championship tournaments.

Open blitz tournaments are played for 21 rounds using the Swiss chess pairing system. In contrast, women's blitz tournaments are played with either 17 or 21 Swiss pairing rounds, depending on the year of the tournament.¹⁰ The Swiss pairing system is the most commonly used tournament format in competitive chess, which essentially pairs players with similar cumulative running total scores in the tournament. Blitz chess games are limited to three minutes per game per player, with two seconds added to the player's clock after each move.

Games played by players, who do not play the whole tournament, and games against opponents with unrated blitz ratings are not included in the dataset.¹¹⁾ This yields 18,530 observations from 647 players. The summary statistics for the data are presented in Table 1.

The players' average FIDE Elo rating, which describes the relative skill levels of players, is 2590.9 in the open tournaments and 2299.1 in the women's tournaments. In both the open and women's tournaments, the highest number of winning streaks is eight games, while the highest number of losing streaks is seven games. The variable *WHITE* is included in the summary statistics since players playing with the white chess pieces make the first move, and therefore, have a first-move advantage.

Players' FIDE Elo ratings are used to calculate the expected score from each game. The expected score is calculated as follows:¹²⁾

$$Expected \ Score = \frac{1}{\left[1+10^{\left(\frac{R(B)-R(A)}{400}\right)}\right]} \tag{1}$$

In the above equation, R(A) represents a given player's Elo rating, while R(B) represents the given player's opponent's Elo rating. The expected score is a continuous variable between 0 (loss) and 1 (win). When players have equal ratings, the expected score equals $\frac{1}{2}$, which is considered a draw in terms of

⁶⁾ chess-results.com. Accessed October 20, 2019.

⁷⁾ The Open World Blitz Championship generally takes place each year. The 2015 Women's World Blitz Championship is not included in the dataset due to the event being canceled. Furthermore, the data from the 2014 Women's World Blitz Championship is not included since the tournament organizers experimented with different chess rules that permitted a game to end with one of five possible outcomes instead of the traditional three-game outcomes of win, loss, or draw.

⁸⁾ In this data sample, only two female chess grandmasters can be identified as having played in the open blitz tournaments.

⁹⁾ Due to its popularity, the live streaming of chess quadrupled its number of viewing hours on Twitch between March 2020 and August 2020 when compared to the previous six months (Browning 2020). In the aftermath of the airing of Netflix's "The Queen's Gambit", the sale of chess sets has increased by 125%, and Chess.com, a popular online game website, has been registering 100,000 new players a day while hosting more than 1 million games per day (Fazio 2020; Dean 2020).

¹⁰⁾ Women's World Blitz Chess Championship tournaments are

played for fewer rounds due to the fewer number of participants.

¹¹⁾ It should be noted that FIDE Elo ratings include a time control category, and some titled players may not have a blitz chess rating even though they have a chess performance rating under classical time control.

¹²⁾ Equation (1) is appropriate to use in our analysis because this is the actual formula that forms the base of Elo rating calculations (Glickman and Jones 1999). A detailed discussion of Elo rating derivation and its statistical properties are presented in Elo (1986).

Variable –	Combined		Open		Women's	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
SCORE	0.5144	0.4453	0.5167	0.4422	0.5070	0.4550
RATING	2520.9	212.0	2590.9	174.9	2299.1	160.1
WIN 1	0.3968	0.4892	0.3918	0.4882	0.4123	0.4923
WIN ²	0.1371	0.3439	0.1313	0.3378	0.1552	0.3621
WIN ³	0.0454	0.2083	0.0418	0.2001	0.0570	0.2318
WIN ⁴	0.0142	0.1183	0.0128	0.1124	0.0186	0.1352
WIN ⁵	0.0039	0.0622	0.0032	0.0565	0.0061	0.0776
WIN ⁶	0.0011	0.0336	0.0009	0.0292	0.0020	0.0449
WIN ⁷	0.0004	0.0194	0.0003	0.0169	0.0007	0.0259
WIN ⁸	0.0002	0.0127	0.0001	0.0119	0.0002	0.0150
LOSS 1	0.3600	0.4800	0.3569	0.4791	0.3700	0.4828
LOSS ²	0.1241	0.3297	0.1202	0.3252	0.1365	0.3434
LOSS ³	0.0420	0.2007	0.0399	0.1958	0.0487	0.2152
LOSS 4	0.0138	0.1165	0.0119	0.1086	0.0195	0.1383
LOSS 5	0.0045	0.0672	0.0033	0.0571	0.0085	0.0919
LOSS ⁶	0.0017	0.0409	0.0009	0.0304	0.0040	0.0634
LOSS 7	0.0008	0.0275	0.0002	0.0146	0.0025	0.0496
WHITE	0.4999	0.5000	0.5001	0.5000	0.4996	0.5001
Ν	18,	530	14,	,070	4,4	460

Table 1. Summary statistics

skill. As noted earlier, an Elo difference of paired players is deemed a reliable predictor of a match.

IV. Empirical Results

A fixed effects regression model is estimated with the actual score from a game being used as the dependent variable. The objective is to analyze how winning and losing streaks affect performance relative to the expected performance given player strengths.

The independent variables include the players' expected score from the game, winning or losing streaks, and a dummy variable indicating whether a player is playing with the white chess pieces. The winning streaks are denoted as WIN_i where $i = \{1, \dots, 7\}$ and the losing streak are denoted as $LOSS_j$ where $j = \{1, \dots, 7\}$. For example, WIN_i indicates that the player has won the last *i-number* of games; alternatively, $LOSS_j$ indicates that the player has lost the last *j-number* of games. The fixed effects control for the time-invariant, player-specific factors that could be correlated with the other independent variables.

Table 2 presents the estimated regression results.

Regressions are estimated using (i.) combined data from the open and women's tournaments; (ii.) data from the Open World Blitz Championship; (iii.) data from the Women's World Blitz Chess Championship; (iv.) players with Elo ratings below 2700 from both the open and women's tournaments, and (v.) players with Elo ratings greater than or equal to 2700 from both the open and women's tournaments. In chess, players rated 2,700 or higher are considered very highly ranked players and are frequently referred to as super grandmasters.¹³⁾

As predicted, the expected score calculated from the players' ratings difference has a statistically significant positive effect on the actual score at a 1% significance level in all regressions. Thus, players' ratings are the main predictor of the game's outcome. The expected score has the largest estimated coefficient for players rated at and above 2700 Elo points. One plausible explanation is that the performance levels are more consistent for the higher-rated players, and therefore, are more closely aligned with the rating differences. In addition, as predicted, the players, who played

¹³⁾ Super grandmaster is not an official FIDE chess title, but it is one commonly used in the chess community.

Variable	Combined	Open	Women's	Rating < 2700	Rating >= 2700
EXP SCORE	0.8458***	0.8825***	0.7325***	0.8564***	0.9753***
WIN_1	-0.0026	-0.0049	0.0039	-0.0072	0.0175
WIN_2	0.0115	0.0089	0.0189	0.0112	0.0181
WIN_3	0.0087	0.0255	-0.0375	0.0151	-0.0101
WIN_4	-0.0169	-0.0497	0.0591	-0.0251	0.0150
WIN_5	0.0167	0.0183	-0.0055	0.0406	-0.0313
WIN_6	0.0992	0.0580	0.1338	0.1284	0.0355
WIN_7	0.3084	0.5644*	0.0478	0.2611	
WIN_8	-0.6743**	-0.7737*	-0.6671	-0.6737**	
LOSS_1	0.0263***	0.0342***	-0.0016	0.0184*	0.0619***
LOSS_2	0.0077	-0.0035	0.0432*	0.0067	0.0302
LOSS_3	-0.0022	-0.0011	-0.0090	-0.0029	0.0301
LOSS_4	0.0245	0.0123	0.0504	0.0288	-0.2637
LOSS_5	-0.0145	-0.0170	-0.0208	-0.0167	
LOSS_6	0.1476	0.2984**	-0.0853	0.1473	
LOSS_7	0.0271	0.0480	0.1773	0.0286	
WHITE	0.0598***	0.0658***	0.0406***	0.0580***	0.0675***
Constant	0.0935	-0.0951	0.1699***	0.0927	0.0974
Ν	18,530	14,070	4,460	15,590	2,940
R2	0.1573	0.1665	0.1360	0.1592	0.10892
F	5.03***	5.48***	3.62***	4.69***	3.51***

Table 2. Regression results from the fixed effects model

* Significant at 10% level, ** significant at 5% level, ***significant at 1% level.

white, had higher scores. The effect is statistically significant at the 1% significance level in all regressions. The magnitude of the effect is between 0.04 and 0.068. This corresponds to approximately one additional win in every 15 to 25 games, or a rating improvement of 28 to 47 points for a player playing white against an opponent with an equal Elo rating.

Looking at the pattern of winning and losing streaks, the data supports neither the hot hand nor the cold hand hypotheses. The hot hand hypothesis implies that wins improve performance in the next game. The estimated coefficients of the winning streak variables are either statistically insignificant or have a negative sign with one exception. The exception regards the estimated coefficient of the *WIN_7* variable, which is positive and statistically significant at the 10% significance level when using data from the Open World Blitz Championship. Hence, the hot hand hypothesis is not supported.

Symmetrical to the hot hand, the cold hand hypothesis implies that losses lower performance in the next game, and therefore, the estimated coefficients should be negative for losing streaks. The coefficients of these variables from the regressions are either positive or statistically insignificant. Therefore, the data does not support the cold hand hypothesis.

The estimated regression results show evidence of a performance reversal following a loss. The variable, LOSS 1, is statistically significant at the 1% significance level in three regressions (combined data, open tournament data, and rated 2700 and above data) and at a 10 percent level in one regression (rated below 2700 data). The estimated coefficient of the variable is positive. This indicates that losing a game improves a player's performance relative to their rating in the next game. The magnitudes of the estimated coefficients range between 0.018 and 0.062, corresponding to approximately a 13 to 43 rating points improvement when a player faces an opponent with an equal rating level. With a couple of exceptions, the estimated coefficients of the losing streak variables, i.e., LOSS j for j > l, are not statistically significant. This implies that losing more than one game in a row is unlikely to influence subsequent performance; the performanceenhancing effect is from losing the last game and not from a cumulative loss of games.

In women's tournaments, *LOSS_1* is statistically insignificant. *LOSS_2* is statistically significant (at the

10% level) with a positive coefficient in women's tournaments. The coefficients of *WIN_8* are also statistically significant in three regressions. However, clear conclusions regarding the latter result cannot be made because only three players in the dataset had an eight-win streak. Further analysis using an expanded data set is needed to investigate the effects of longer winning streaks.

We note that F-tests are significant, while R-squared values are between 10-20% in our regressions. One of the explanations for this result is the nature of blitz games. Chess fans find blitz chess tournaments exciting because a fewer percentage of games end in draws, and it is not uncommon for a strong player to lose to a much weaker player. This, however, makes it harder to predict the outcome of individual games and yields lower R-squared values for our estimated models.

V. Conclusion

The effect of performance streaks on subsequent performance is of interest in behavioral economics. The paper contributes to this literature by looking into competitive blitz chess, where psychological factors are more important than physiological factors. The data does not support either the hot hand or the cold hand hypotheses. However, the analysis identifies a bounce-back effect, which has not vet previously been investigated in the empirical literature. The regression results show a statistically significant improvement in a player's performance levels after losing a game. It is hypothesized that this effect is due to either increased player motivation or concentration after losing a game. Future research on this issue could be warranted. It is important to note that the bounce back-effect differs from the regression to the mean effect, which is also a part of this literature in behavioral economics (Gilovich 1991). Regression to the mean assumes that performance fluctuates around a specific mean, while these results show

a statistically significant improvement above a player's average performance level. Looking into the differences between open and women's tournaments, the bounceback effect from losing the last game is observed in open tournaments but not in the women's tournaments. Future research may shed light on the reasons for this difference.

It might be tempting to amalgamate the bounceback effect to the predictions of Learning Theory, which has three main branches, which are Behaviorism, Cognitive Constructivism, and Social Constructivism, but this would not be accurate. In general, a broad definition of learning is that practice or experience leads to a permanent change, according to Lachlan (1997), which is not aligned with the bounce-back effect.

The bounce-back effect does not fit into Behaviorism and Thorndike's Law of Effect, which states that a behavior has a higher probability of being repeated if the stimuli are positive in nature (Bélanger 2011, De Houwer et al., 2013). This, indeed, differs from the bounce-back effect, which states that a loss in Blitz chess motivates the losing player to "bounce back" and win the next match. Regarding Cognitive Constructivism, which is tied to Gestalt Theory, a learner through the process of trial and error is able to move to the answers, and thereby, gain that Eureka moment, which is very similar to Rational Expectations. With Rational Expectations, a person is able to update their information set so that their future forecasts are optimal (Muth 1961). With the bounce-back effect and the speed of blitz chess, there is no process of trial and error that permits the player to sequentially move towards a win. For the third branch of Learning Theory, Jonassen (1991) states that (Social) Constructivism regards the learner creating reality or knowledge based on the person's own experiences with there being no universal reality or knowledge. With blitz chess, there is consensus on what constitutes a win and a loss, so Social Constructivism is not applicable to blitz chess or the bounce-back effect. Hence, the bounce-back effect, which states that a losing player has a slightly higher probability of winning the next match is not aligned with the three main Learning Theories of Behaviorism, Cognitive Constructivism, and Social Constructivism.

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Author	Data/Seasons	Hot or Cold Hand Outcome (Yes/No/Mixed)	
American Football			
Badarinathi & Kochman (1994)	1983-92 NFL Seasons	Yes for hot hand. Finds that betting against teams with winning streaks to be profitable.	
Paul, Weinbach, & Humpreys (2014)	2005-2006 and 2009-2010 NFL Seasons	Yes for hot hand. Teams with 3 or 4 game-winning streaks increases betting and the reverse is found to be true as well.	
Baseball			
Albert & Williamson (2001)	Simulated Data	No for hot hand. Uses a Bayesian model to detect baseball hitting streaks.	
Shea (2014)	2004-2012 MLB's Home Run Derby	Yes for hot hand. When there is no defense with respect to the MLB's Home Run Derby since there is very limited defense.	
Green & Zwiebel (2017)	2000-2011 MLB Seasons	Yes for hot hand. In 5 statistical categories in baseball for hitters and 5 statistical categories pitchers.	
Basketball			
Taylor & Demick (1994)	Five games from the 1990 NCAA Men's Basketball Championships	Yes for Hot Hand. Winning teams have higher probability of favorable outcomes.	
Albert & Williamson (2001)	Simulated Data	No. Uses simulated data in a Bayesian model to detect basketball shooting streaks.	
Attali (2013)	2010-2011 NBA Season	Mixed. A win by a player makes a player take riskier shots with a great probability of a loss but a win makes a coach less likely to replace the player. Also has possible regression to the mean.	
Camerer (1989)	1983-1983 NBA Season	Yes for hot hand. Finds that betting on teams with winning streaks to not be profitable the reverse is found to be true as well.	
Castel, Rossi, & McGillivray (2012)	Survey of 455 people with 22-90 age range.	Mixed. Older people more likely to believe in hot hand when compared to younger people.	
Gilovich, Vallone, & Tversky (1985)	1987-1988 NBA Season (Selected Players)	No for Hot Hand. Finds that subsequent shots are independent of previous shots.	
Shea (2014)	2009-2012 NBA's 3-point Shootout.	Yes for hot hand. Given there is no defense with respect to the NBA's 3-point Shootout. Also has possible regression to the mean.	
Waggoner, Wines, Soebbing, Seifried, & Martinez (2014)	1979-2013 NBA Seasons	Yes for hot hand. Finds seasonal variation in how winning and losing streaks affect point spreads for betting but not game outcomes. Also have Gambler's Fallacy with respect to betting.	
Bowling			
Yaari & David (2012)	2002-2011 PBA Seasons	Mixed. Do not seem to have a hot hand in individual games, but have hot hand when examining games in aggregate.	
Abrevaya (2002)	1991-1997 PBA	Yes for hot hand. Previous wins for underdogs, impacts performance and creates winning streaks in the short-run but have regression to the mean in the long-run.	
Darts			
Gilden & Wilson (1995)	8 paid recruits with previous dart-throwing experience with each set consisting of 300 dart throws. 4 Paid recruits to throw darts and to putt golf balls.	Mixed. Does not find Hot Hand in Darts alone but finds moderate evidence of winning streaks in tournaments consisting of both golf and darts.	

Appendix 1. Literature review summary

Appendix 1. Continued

Author	Data/Seasons	Hot or Cold Hand Outcome (Yes/No/Mixed)
Darts		
Stins, Yaari, Wijmer, Burger, & Beek (2018)	Examines 8 official matches between 2012-2015 for each of the 10 best ranked dart throwers	No for hot hand. Finds some sequential dependence and non-stationarity, which is contrary to the hot hand, which refers to a stationary random independent process.
Golf		
Gilden & Wilson (1995)	Paid recruits for a session consisting of 300 putts^{-1} st Group consisted of 40 players and 2^{nd} group consisted of 5 players and the distance varied.	Yes for hot hand. Winning streaks could be due to no interruption provided by experiment design.
Livingston (2012)	4 golf tournaments in 2006: Nationwide; PGA; LPGA; and Champions Tour.	Mixed. Only have hot hand in Nationwide Tour, which has younger, more inexperienced golfers. Short winning or losing streaks are incorrectly attributed to the hot or cold hand.
Arkes (2016)	Top 200 golfers of the PGA Tour from 2003-2013.	Mixed. No hot hand effect but does find large cold hand effect.
Soccer		
Parsons & Rodhe (2015)	20 teams for 3 seasons of the English Premier League (EPL) from 2010-2013.	Mixed. Have negative momentum (cold hand) effect following winning streaks. Robust causal momentum of hot hand cannot be determined. No hot hand for individual players within games.
Jordet, Hartman, & Vuijk (2011)	Penalty shootouts for World Cup and European Championships from 1976 to 2006	Yes for cold hand. Teams with preceding loses performed worse in penalty shootouts.
Table Tennis		
Briki, Den Hartigh, Hauw, & Gernigon (2012)	(Table Tennis and Swimming) 4 table tennis players and 4 Swimmers with national and international experience from clubs in the south of France. Have average of 3.9 years of experience	Mixed but favoring hot hand. More ways to trigger negative psychological momentum (PM) than positive PM with "mastery orientation" boosted positive PM and helps to lessen negative PM.
Den Hartigh & Gernigon (2018)	(Table Tennis Only) 80 competitive table tennis players from the Netherlands in structured experiment	Mixed for cold hand. Calling time-out can diminish a winning streak but it can help to reverse a losing streak. A losing streak at the beginning of a game has less of an impact than a losing streak at the end of the game.
Tennis		
Taylor & Demick (1994)	1990 Men's and Women's U.S. Open Tennis Championships -5 matches from the quarterfinal and semifinal rounds	Hot Hand and Cold Hand. Winning players have higher probability of favorable outcomes than negative outcomes. Losing players have a higher probability of negative outcome.
Malueg & Yates (2010)	ATP tennis matches from 2002 to 2006- over 14,000 matches with players of differing abilities.	Mixed. Reject null of tennis matches ending in two sets. Winner of 1^{st} set not able to capitalize on 1^{st} win and take the second set (No hot hand). When match goes to 3 sets, winner of the 2^{nd} has high probability of winning the 3^{rd} set (Have hot hand).
Volleyball		
Raab, Gula, & Gigerenzer (2012)	26 male players in Germany's first-division volleyball league and 16 coaches from Berlin with a B- or C-level coaching license in volleyball	Yes for hot hand. Finds winning streaks for about 50% of the players. Both coaches and players are able to detect winning streaks and use them advantageously.
Raab & MacMahon (2015)	Twenty-nine students who majored in sport at a university where of the participants are 15 male and 14 female)	No for hot hand. Results depended on how the winning streak was framed.