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# Psychological momentum among non-experts: Evidence from club golfers☆

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ABSTRACT

This study examines the link between psychological momentum and performance. In sporting settings, the notion that prior performance may influence future outcomes is a familiar one to fans and athletes alike. However, the identification of a causal relationship between psychological momentum and subsequent performance is complicated by the need to control for the ability of a player and the situational context. Furthermore, studies focused on professional athletes may understate results due to the well-practiced nature of such individuals. To address these challenges, we develop a novel method of isolating the effects of a change in psychological momentum. Using data from club golf competitions, we find evidence of a cold-hand effect among both male and female players. We also find evidence of a hot-hand effect among male players only. Investigations into the individual playing characteristics that drive psychological momentum reveal that male players who can keep a cool head during periods of success and failure perform better. Conversely, males who are prone to cold-hand effects perform worse. Our results can be placed in context with the existing literature, which primarily examines professional athletes.

## 1. Introduction

Momentum's influence on subsequent performance in sporting contests is a topic of much debate. In particular, the importance of psychological momentum has been the subject of conjecture among athletes, fans and economists alike. Iso-Ahola and Dotson (2014, p.20) describe psychological momentum as "an altered and felt state of mind in which a performer senses things going unstoppably his or her way". Psychological momentum therefore stems from a change in cognition that affects a competitor's perceptions which, as a result, may influence future outcomes. The idea that success breeds success is a familiar one to athletes who often credit good performances to positive beliefs stemming from earlier positive outcomes. Fans have also been found to hold similar beliefs regarding the importance of successful streaks (Markman & Guenther, 2007).

Despite its anecdotal importance, early research found limited empirical evidence to support psychological momentum's influence on future performance. Seminal work by Gilovich et al. (1985) described people's tendency to see positive streaks of success in basketball shooting as evidence of psychological momentum a 'cognitive illusion'. This result gave rise to the 'hot-hand fallacy', a related phenomenon that has since become synonymous with the misperception of random sequences. In a review of the literature that followed over the next twenty years, Bar-Eli et al. (2006) found a relatively even number of studies in support of psychological momentum, compared to non-supportive ones, across an array of sports.

Recently, several studies have highlighted a variety of limitations in the early hot hand literature. Stone (2012) suggests that standard analyses of the hot hand phenomenon are prone to severe measurement error, implying that belief in the hot hand is not necessarily a cognitive fallacy. Similarly, Arkes (2013) demonstrates that the primary methods for estimating hot hand and momentum effects have a low chance of detecting significance, leading to the existence of the effects being understated. Miller and Sanjurjo (2018) reveal a large statistical bias in the measures used by Gilovich et al. (1985). Upon correcting for this bias, the authors find strong evidence of hot hand shooting in basketball. In related work, Miller and Sanjurjo (2021) note that evidence of the hot hand extends to controlled basketball shooting experiments at the professional, semi-professional and collegiate levels.

The recent correction of the hot-hand fallacy is a testament to the difficulties associated with empirical analysis of psychological momentum. Identification of a causal relationship between psychological momentum and subsequent performance presents two key challenges. The first challenge relates to the issue of ability. As noted by Gauriot and Page (2019), identification of momentum is typically underpinned

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by the assumption that the underlying ability or skill of a participant remains constant over the course of a study. Even in short-term sporting settings, there are several circumstances (such as injury, fatigue or substitutions) that may result in violation of this assumption. It is also possible that what is perceived as psychological momentum may simply be greater skill on the part of the participant. Therefore, controlling for overall ability is an important but non-trivial task.

The second challenge concerns the possibility that psychological momentum may coexist with strategic momentum. Iso-Ahola and Dotson (2014) highlight that psychological momentum is a temporary and short-lived phenomenon that can easily be disrupted by external events. Many sporting settings are, however, multi-stage contests where strategy and style of play may be dependant upon the score in a particular game, the amount of time remaining or the stage of the season. Estimates of the effect of psychological momentum may therefore be confounded by the presence of strategic momentum in an overlapping period.

To address these challenges we use a unique data set of hole-by-hole scores from club golf competitions. This data helps to deal with the issue of heterogeneous ability in two ways. Firstly, we use net scores, which take into account handicaps that allow players of all levels of ability to compete against one another on a level playing field. Handicaps are a distinctive feature of competitive golf below the professional level.[1] From the perspective of data analysis, a player's daily handicap gives us a reliable exogenous indicator of their ability before their round commences. The dynamic nature of the handicapping system also helps to deal with slow variation in player ability across many rounds of golf.[2] Secondly, recognising that player ability may vary *within* a round, we take into account that there may be short passages of play during which a player exhibits a relatively good or bad streak which is not a response to psychological momentum.

The use of hole-by-hole scores among club golfers also helps to alleviate concerns regarding any confounding strategic momentum effects. Hole-by-hole scores provide an objective measure of short-term success and failure. Typically, golfers will only have a matter of minutes in which to cognitively process previous performance after one hole before making a subsequent attempt. As noted by Iso-Ahola and Dotson (2014), the perceived link between two closely occurring events is critical for the formation of psychological momentum. Furthermore, the individualistic nature of the sport means that golfers typically lack direct competitors. Unlike many competitive sports, golf is not subject to endogenous defensive responses or substitutions that could potentially bias results (Green & Zwiebel, 2018).

Club golf competitions often take place over the course of an entire day. As a result, it is not uncommon for some players to complete their rounds before others have even commenced. Therefore, it is plausible to assume that the average performance from one hole to the next is not greatly influenced by the player considering the strategic status of the competition. It should also be noted that golf is well known for being more of a mental game than a physical one. As a result, it is highly suited to examinations of psychological momentum.[3] On a hole-by-hole basis, players are more likely to be affected by positive or negative emotions than factors relating to strategic momentum.

In this paper, we develop a novel method of isolating the effect of a change in psychological momentum based on the scores for a player on the two prior holes. We classify prior hole scores as being bad, neutral or good. We then define and measure responses to positive momentum switches from neutral to good, and responses to negative switches from neutral to bad. We find that consecutive hole scores tend to be positively autocorrelated, so in our method we are careful to isolate the possible effect of the *switch* in momentum from the predictive power of the *level* of the recent scores. This empirical strategy builds upon existing studies that also exploit variations in the timing of events to identify the impact of psychological momentum in a variety of professional sporting settings (Cohen-Zada et al., 2017; Gauriot & Page, 2018; Page & Coates, 2017).

We use the labels "hot hand" to describe tendencies to follow positive momentum switches with good scores, and "cold hand" for tendencies to follow negative switches with bad scores. A unique contribution of this paper is that we go beyond the initial tests for the existence of hot and cold hand effects and examine whether the presence of these psychological characteristics is associated with being a better or worse golfer. We do this by examining the range of responses for individual players to see if there is an association between ability (as reflected by player handicap) and the degree of emotional response to prior hole performance.[4] The use of scoring data from club golfers with a wide range of ability is particularly suited to this analysis, since a more accurate estimate of the slope of the relationship can be made than would be the case using data from professional golfers who tend to have a much tighter range of ability. We are not aware of any other attempts to do this using club golf data in the literature.

The results also permit the examination of gender-specific responses to switches in psychological momentum. We find that both genders show a highly significant tendency for a worse expected score on the hole following a negative momentum switch, which we label as a cold-hand effect. Men, but not women, also show a significant tendency to a better expected score on the hole following a positive momentum switch, which we label as a hot-hand effect. On an individual level, we find that having a cold hand tendency amongst men is associated with having a higher handicap (being a worse player), but not for women. The *absence* of emotional responses to positive and negative momentum switches, which we label as maintaining a 'cool head', is significantly associated with a lower handicap for men (being a better player).

## 2. Empirical strategy

### 2.1. Data collection

We use hole-by-hole scores from club competitions at the Concord Golf Club (New South Wales, Australia) for the years 2019–2020. Club competitions are only open to players with an official handicap and the formal Rules of Golf are applied. The ability of Club members ranges from beginner through to expert, reflected in a difference of about 50 strokes between the highest and lowest member handicap. It would be appropriate to describe the average member as an ordinary, non-expert golfer. Almost all scores were recorded with a hand-held electronic device. It was desirable to use competition data for this analysis because we can assume that players were trying to do their best and that the *bona fides* of recorded scores were checked by an independent marker. Anomalies such as incomplete rounds and other invalid scores were removed which left data from 59,021 complete rounds of 18 holes (1,062,378 observations) in Stableford competition format, including both male and female players. Many players have multiple rounds in the sample.

[1] Most competitions for club golfers around the world are handicapped. Individual player handicaps are managed according to rules set out by the World Handicap System. Accordingly, handicaps are transportable, so that players can compete away from their home club using a system that also takes into account the relative difficulty of the course on which they play.

[2] Several existing studies also utilise golfing data to examine various links between performance and momentum at the professional (Arkes, 2016; Evans & Crosby, 2021; Livingston, 2012; Rosenqvist & Skans, 2015) and youth levels (Cotton et al., 2019). Given the absence of a handicapping system at these levels, such studies tend to incorporate a variety of simple measures with which to control for ability.

[3] As golf is particularly mentally challenging, estimates of psychological momentum are likely to be towards the upper bound. Examinations of psychological momentum in less cognitively demanding settings would likely yield smaller effects in absolute terms.

[4] As noted by Livingston (2012), mean impacts may mask differences in how individual players react to streaks of success and failure.

### 2.2. Golf handicap

A feature of club competition golf worldwide is the use of handicaps to allow players of widely ranging ability to compete in the same competition while creating a level playing field. Net scores, which take into account a player's handicap, are used for the analysis. As noted by Franke (2012), a high level of heterogeneity in player ability reduces competitive pressure and weakens underlying incentive structures. So, using net scores alleviates the issue and ensures that our analysis will be based on the scores from competitive play.

Some readers will be familiar with the Stroke Play golf competition format in which players simply aggregate the gross number of strokes taken to complete a specified number of rounds of the course and the lowest aggregate score wins. In handicapped Stroke Play, the players simply deduct their handicap from the aggregate gross score to give a net score (for example, a gross score of 80 for one round for a player with a handicap of 6 yields a net score of 74). The application of handicaps in the Stableford competition format is more complicated and is explained in the following section.

### 2.3. Stableford competition format

The typical format in Australian club golf competitions (including those played at Concord Golf Club) is the Stableford format. The primary reason for using Stableford scoring data for this analysis is that the sample size is much larger than we were able to collect from Stroke Play competitions. The Stableford scoring system allows players to accumulate "points" hole by hole during a round. A higher number of Stableford points is better than a lower number and zero is the lowest possible number of points per hole. The format is designed to improve the enjoyment of the sport, as well as pace of play, since a player facing an inevitable zero-point score after several bad shots can simply elect to record zero points and move on to the next hole.

The Par of a hole (3, 4 or 5) is the expected number of strokes for a highly competent player. The easiest way to interpret the handicapped Stableford scoring system is to use the concept of an Adjusted Par. For example, on a designated Par 5 hole, if a player receives 1 extra handicap shot on that hole, then the Adjusted Par is 6. A player earns 2 points for playing a hole to Adjusted Par, with one point added (subtracted) for every additional gross stroke by which their score is better (worse) than Adjusted Par. We can express that by formula, where the Stableford score per hole is equal to $max[0, 2 + AdjustedPar - GrossScore]$.

Since the Stableford score is calculated hole by hole, it is necessary to allocate a player's handicap to specific holes. For example, a player with a 6 handicap is allowed 1 extra shot on the 6 most difficult holes, and no extra shots on the other 12 holes. Club management determines a Hole Index table which ranks the holes in order of difficulty, with Hole Index 1 meaning the most difficult and 18 meaning the least difficult. An illustrative scorecard is shown in the Appendix which shows how Stableford scores are calculated taking into account the Hole Index.

### 2.4. Asymmetry of scores

We motivate the study by illustrating two readily apparent properties of scores on consecutive holes which are asymmetry and persistence. Firstly, we illustrate the asymmetric relationship between the score on the current hole and the immediately prior hole, depending on whether the prior performance was good or bad. Specifically, we estimate the following simple regression:

$$S_j = \beta_0 + \beta_1 ps0_j + \beta_2 ps1_j + \beta_3 ps3_j + \beta_4 ps4b_j + \varepsilon_j, \quad (1)$$

where $S_j$ is the Stableford score on hole $j$ for a given player and $ps0_j$ is an indicator variable set to 1 when the Stableford score on the hole played immediately prior to hole $j$ was equal to 0. The variables $ps1_j$ and $ps3_j$ indicate prior scores of 1 and 3 respectively and $ps4b_j$ indicates a prior score of 4 or better.[5] The intercept $\beta_0$ represents the expected score in the reference case when the prior hole score was 2. Table 1 presents the OLS results for Eq. (1). The mode Stableford score per hole is 2 (about 42% of the sample) with a mean of 1.697. We observe that prior hole scores worse than the mode have negative coefficients in the regression model, showing that they are associated with a lower (worse) expected score on the current hole. Conversely, prior hole scores better than the mode are associated with a better (higher) expected scores on the current hole.

**Table 1**
Asymmetric responses to prior hole scores.

| Explanatory variable | (1) |
|---|---|
| *ps0* | −0.079*** |
| | (0.003) |
| *ps1* | −0.024*** |
| | (0.002) |
| *ps3* | 0.016*** |
| | (0.003) |
| *ps4b* | 0.027*** |
| | (0.008) |
| *Constant* | 1.713*** |
| | (0.001) |
| $R^2$ | 0.001 |
| N | 1,003,357 |

Notes: Dependent variable is Stableford score; first observation dropped in each round for no prior hole; standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 1 also exhibits asymmetry in the relationships, with the absolute magnitude of responses to bad prior scores being much larger than the response to good prior scores. This may be evidence of a psychological characteristic which has often been observed in fields much wider than just golf where there are asymmetric subjective responses to gains and losses and that, in particular, there are stronger emotional responses to losses than gains (Baumeister et al., 2001; Yechiam & Hochman, 2013). We observe that the coefficient of $ps0_j$ has more than double the absolute value of the coefficient of $ps1_j$, so it appears that a prior score two shots below the mode may have more than twice the impact of a score one shot worse than the mode. Responses are flatter on the upside than on the downside, since the coefficient of $ps3_j$ is less in absolute value than that of $ps1_j$, noting that scores of 1 and 3 are each one shot away from the mode score of 2. Finally, the coefficient for $ps4b_j$ is less than double that of $ps3_j$. The results provide *prima facie* evidence that there is a positive association between current and prior hole scores and that sensitivity to prior bad scores increases in a non-linear fashion.

### 2.5. Persistence

Scores by individual players on consecutive holes appear to be very persistent, i.e. there is positive correlation between the score on the current hole and the prior hole, possibly running to several prior holes. We demonstrate this property by estimating the following simple regression to show the significant positive association between scores on the back nine with those on the front nine:[6]

$$back9_i = \beta_0 + \beta_1 front9_i + \varepsilon_i. \quad (2)$$

For a specific round $i$, we define the variables $front9_i$ and $back9_i$ as the aggregate number of Stableford points for the relevant nine holes minus 18 (which gives the aggregate nine hole score relative to the

[5] Stableford scores of 5 or more on an individual hole are rare, comprising approximately 0.04% of our sample.

[6] In this context, the first 9 holes played in an 18-hole round are called the front 9 and the last played are the back 9, regardless of the starting tee.

**Table 2**
Scoring persistence after 9 holes.

| Explanatory variable | (1) |
|---|---|
| *front9* | 0.165*** |
| | (0.004) |
| *Constant* | −2.376*** |
| | (0.017) |
| $R^2$ | 0.026 |
| N | 59,021 |

Notes: Dependent variable is back9; standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

neutral result of 18 points). In Table 2 we show the estimated regression of Eq. (2). The expected score on the back nine is 2.38 points worse than handicap plus 16.5% of the deviation from handicap on the front nine and the slope coefficient is highly significant. To give a numerical example, a player who drops 6 shots against handicap on the front nine is expected to drop about 1 more shot than would otherwise be expected on the back nine. The result shows that if a player is showing average ability in the medium term which is inconsistent with their handicap level, then that medium-term form can be quite persistent, lasting at least from the front nine to the back nine. Even though the handicapping system is designed to adjust a player's handicap to reflect recent form it does so slowly. Anecdotally, it is quite typical to observe a player performing below (or sometimes above) the skill level suggested by their handicap for several consecutive holes, for an entire round or even across several rounds.

### 2.6. Momentum switches

The aggregate (or average) level of the scores on recent holes is a useful explanatory variable for the conditional expected score on the next hole, due to the persistence of scores (positive autocorrelation). However, in this paper, we want to eliminate the predictive contribution of the aggregate level of recent play and instead look at the impact of changes in the level over recent holes. We will characterise certain changes in the score over the two preceding holes as switches in psychological momentum. For example, consecutive hole-scores of net par followed by net double-bogey would be classed as a negative switch in momentum, whereas consecutive net double-bogeys reflect persistent bad play (which increase the conditional probability of further bad play) but would not be classed as a switch in momentum. We conjecture that there is a possible causal link between a switch in momentum and performance on the next hole.

We draw an analogy with methods in the literature to control for ability and team strength so that the possible effects of psychological momentum are not confounded with streaks of performance which may be due to the relative ability of teams or individual players. In a team sport, a streak of consecutive wins may not be particularly unusual if the team has recent form indicating that they are a relatively strong team in the competition, which can be controlled for in analysis (Gauriot & Page, 2018; Kniffin & Mihalek, 2014; Leard & Doyle, 2011).

Similarly, a streak of consecutive free-throws in basketball for a player who is known to be adept at free-throws provides less compelling evidence of a momentum effect than a hot streak from a bad player, so controls for ability or recent average performance should be used (Cohen-Zada et al., 2017; Cotton et al., 2019). The equivalent step in our methodology for golf analysis is controlling for the aggregate level of the scores on the two prior holes. Due to the persistence of scoring ability in the medium term, a below-average performance even over two holes can be a predictor of below-average performance on the next hole, which could confound attempts to measure the impact of a momentum switch on the most recent prior hole.

In the following sections of the paper, we introduce the explanatory and control variables which allow us to extract a component of the sensitivity to prior hole scores which can be reasonably attributed to a psychological response to prior performance.

### 2.7. Model specification

A pure time series analysis of a sequence of scores on consecutive holes using several lags of the dependent variable as regressors would be problematic. Preliminary analysis shows that if the data is treated in that way then hole-by-hole scores are strongly positively autocorrelated with a long time lag, or are arguably even non-stationary, i.e. players can exhibit passages of play over several holes or across several rounds where their average score is notably different to what would be expected for a player with their handicap. However, in this analysis we are not interested in explaining variation in the ability of the players in the medium term.

Instead, we design a pooled cross-sectional model which includes some indicators of performance based only on the two most recent prior holes. We aim to control for the influence of the aggregate level of the player's score on the two prior holes and measure only the change which may be attributable to a change in momentum in the two prior holes, such as switching from a good score to a bad score.

Explanatory variables are derived using indicators of prior two-hole sequences. We use a hole score of 2 Stableford points on the second prior hole as a neutral reference point, since it is the explicit benchmark for 'playing a hole to handicap' and it is also the most frequently observed outcome. Then we isolate switches away from the neutral reference point in prior two-hole sequences. For example, a prior two-hole sequence going from 2 to 3 Stableford points (net par to net birdie) is characterised as a positive switch in psychological momentum, whereas a sequence going from 2 to 0 (net par to net double bogey or worse) is characterised as a negative switch in psychological momentum. In doing so we conjecture that the emotional response of the player is connected to the change in momentum. So, a switch from 2 to 3 feels "good", and a switch from 2 to 0 feels "bad". By the same method, we derive indicators for switches from 2 to 1 (negative) and 2 to 4 (positive). Whilst there are many possible prior sequences we could examine (including sequences longer than two prior holes) we limit our analysis to those stated above. The emotional response to other sequences such as switching between two extreme scores (such as from 0 to 4, or vice versa) is more difficult to characterise since neither of the two prior holes were neutral outcomes.

Now we show how the indicator variables are used in a regression to estimate the sensitivity of the current hole score to the prior sequences. This is best explained with a specific example. Let the indicator variable *seq20* equal 1 when the prior two-hole sequence was 2 then 0. Sensitivity of the expected score on the next hole to the prior sequence *seq20* is part of our measure of sensitivity to a negative switch in momentum. However, we note that in the scoring sequence *seq20* the player has played two strokes worse than handicap in aggregate over two holes (playing to handicap requires an average of 2 points per hole). We find that *seq20* is associated with a lower expected score on the next hole and we assume this is due in some part to the persistence of scores and not necessarily attributable to a psychological response to the switch in momentum.

We need another explanatory variable to remove the effect of persistence. A convenient and intuitive choice is another sequence indicator, *seq02*, which is the same two scores but in the opposite order, so achieving the same two-hole aggregate. In this case, the most recent hole score was 2, which is considered neutral. We argue that the most recent hole performance is likely to drive the emotional response on the next hole. Accordingly, it is reasonable to contend that *seq02* is not likely to generate an emotional response which is carried to the next hole. In the following regression analysis, we will use the difference between the coefficients of this pair of sequence indicators as our measure of the sensitivity of the score on the next hole to a prior negative switch in momentum. By taking the difference between the coefficients we can measure the effect of the order of the sequences independent of the two-hole aggregate score which is common to both *seq20* and *seq02*. The sensitivity to the negative switch in momentum

**Table 3**
Share of score sequences.

| Score sequence | Percentage |
|---|---|
| *seq20* | 5% |
| *seq02* | 5% |
| *seq21* | 11% |
| *seq12* | 11% |
| *seq23* | 7% |
| *seq32* | 8% |
| *seq24* | 1% |
| *seq42* | 1% |

Notes: There are 16 observations per round with at least 2 prior holes.

would likely be overstated were it not for the use of *seq02* as a further control.

The following regression is estimated:

$$S_{ij} = \alpha_0 + \gamma_0 seq20_{ij} + \gamma_1 seq02_{ij} + \gamma_2 seq21_{ij} + \gamma_3 seq12_{ij} + \gamma_4 seq23_{ij} + \gamma_5 seq32_{ij} + \gamma_6 seq24_{ij} + \gamma_7 seq42_{ij} + \delta_{ij} + \varepsilon_{ij}, \quad (3)$$

where $S_{ij}$ is the Stableford score for the player during round $i$ on hole $j$ and $\delta_{ij}$ is a set of fixed effects discussed in detail below. Using the same scheme described above, we examine four pairs of sequences of scores on the two holes prior to hole $j$. In each pair we include a neutral score of 2 on hole $(j-2)$ followed by either 0, 1, 3 or 4 on hole $(j-1)$. Then we reverse the order of the scores to complete each pair to create a variable with the same two-hole aggregate to use as a control for the anticipated effect of persistence. In each case, the difference between the first coefficient of the pair and the coefficient of the corresponding control is the measure of interest. Score-sequences *seq20* and *seq21* (and the corresponding controls) indicate a negative switch in momentum, whereas *seq23* and *seq24* indicate a positive switch in momentum. Table 3 presents frequencies for each of the score sequences used in our analysis.

We cannot immediately say that a positive switch in psychological momentum will have a positive impact on subsequent play, and vice versa for a negative switch. For example, one player may tend to benefit from higher confidence after a good score, whereas another may tend to play worse for fear of wasting prior good play. Similarly, some players may fall into a negative funk after a bad hole whilst others may use the emotion to fight harder and bounce back.

We will use labels for combinations of switches in momentum and their effect on subsequent play which closely correspond with their typical use in the hot hand and cold hand literature, i.e., we will use "hot hand" to describe situations where a positive switch in momentum is associated with better following play and "cold hand" where a negative switch in momentum is associated with worse following play.[7] Accordingly, we will perform the following one-sided hypothesis tests for evidence of hot and cold-hand effects based on our measures of sensitivity to switches in momentum:

1. $H_0 : (\gamma_0 - \gamma_1) = 0$ versus $H_1 : (\gamma_0 - \gamma_1) < 0$ (i.e. cold hand)
2. $H_0 : (\gamma_2 - \gamma_3) = 0$ versus $H_1 : (\gamma_2 - \gamma_3) < 0$ (i.e. cold hand)
3. $H_0 : (\gamma_4 - \gamma_5) = 0$ versus $H_1 : (\gamma_4 - \gamma_5) > 0$ (i.e. hot hand)
4. $H_0 : (\gamma_6 - \gamma_7) = 0$ versus $H_1 : (\gamma_6 - \gamma_7) > 0$ (i.e. hot hand)

### *2.8. Control variables*

We use fixed effects to allow for the possibility of variation in the expected score of various subgroups of players or holes which we explain below. Firstly, note that the model specified in Eq. (3) is based on hole-by-hole scores. The handicap system is designed to level the playing field in terms of an aggregate score over an 18-hole round so, even for a specific player, it will not generate an identical expected Stableford score on each hole. The two factors with the largest influence on the expected Stableford score on a particular hole for a particular player are (i) the objective difficulty of the hole, and (ii) the number of handicap strokes allocated to the player on that particular hole. Players receive an integer number of handicap shots per hole based on their 18-hole handicap and the Hole Index (a difficulty ranking described in Section 2.3). We apply a fixed effect by Hole Index to allow for variation in difficulty between holes.

To deal with the second of those factors described above, we define a new variable, Hole Handicap, which is derived from the number of handicap shots the player receives on a particular hole, minus the average number of handicap shots they receive per hole. The intuition behind the approach is that the holes on which it is more (or less) difficult to get a good Stableford score will depend on the player's handicap. For example, consider a player with a handicap of (let us say) 6, who receives a handicap shot for Hole(s) Index 1–6 and none for Hole(s) Index 7–18. For this player, post-handicap, the most difficult hole is likely to be Hole Index 7 because it is the hardest hole with no handicap shot allowed. However, for another player with a handicap of 7, Hole Index 7 would be relatively easy (post handicap) whereas Hole Index 8 would be relatively difficult. We apply a fixed effect by Hole Handicap, which has 35 possible categories.[8]

The three remaining types of fixed effects are more straightforward, the first of which is gender. There is no systematic reason that males and females should have different expected Stableford scores since the handicap system already accounts for individual ability, but we do find a slight difference in average scores by gender in our finite sample. We also apply fixed effects by Hole Par (which is either 3, 4 or 5). The Hole Par should make no difference to the expected Stableford score in an ideal setting, however, the particular demographic of players at the club may find (on average) that holes with a particular par are slightly harder or easier than others. Finally, we apply fixed effects by Grade. Golf Clubs typically classify players into skill level grades A-C (A is the best) by a specified range of handicaps. There are often separate competitions within Grades and the Club tries to maintain a similar sized playing field in each of them by varying the classification range from time to time.[9] Even though every player in the field can compete on a level playing field due to handicaps, it is plausible that the Grade classification could have a small effect on expected scores, for example, a player recently elevated to A-grade may experience a small change their mental approach (conscious or otherwise) which affects their expected score.

Mean Stableford scores grouped by Hole Par, Grade and gender are presented in Table 4.

## 3. Results

### *3.1. Sensitivity to prior score sequences*

Table 5 presents the results of the regression shown in Eq. (3). The estimated coefficients of the score-sequence variables reported

[7] We do not formally test for evidence for possible counterparts to hot hand and cold hand, which could be labelled "bounce-back", where a negative switch leads to good play, nor "hubris" where a positive switch leads to bad play.

[8] We calculated the hole handicap during round $i$ on hole $j$ as the number of handicap shots received by the player on that hole, minus the average number of handicap shots they receive per hole (i.e., the de-meaned handicap shots per hole). For example, if a player has a handicap of 6, they receive 1 extra shot on the 6 hardest holes. In this case, the hole handicap is $(1 - 6/18)$ on the 6 hardest holes, and $-6/18$ on the other 12 holes. As a result the hole handicap variable ranges between $-17/18$ and $17/18$ with an interval of $1/18$, which generates 35 possible levels of hole handicap.

[9] We classified players into grades using daily handicaps (DH) which take into account a base handicap and a slope adjustment for the difficulty of the starting tees. The following thresholds were then used: for men DH $\leq$ 13 "A", DH 14 to 21 "B", DH $\geq$ 22 "C", for women DH $\leq$ 20 "A", DH 21 to 29 "B", DH $\geq$ 30 "C".

**Table 4**
Stableford scores by group.

| Grouping | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| *Hole Par* | | | | | |
| 3 | 236,084 | 1.77 | 0.92 | 0 | 5 |
| 4 | 618,345 | 1.70 | 0.95 | 0 | 6 |
| 5 | 207,949 | 1.60 | 0.98 | 0 | 5 |
| *Grade* | | | | | |
| A | 408,690 | 1.74 | 0.89 | 0 | 5 |
| B | 384,156 | 1.69 | 0.95 | 0 | 5 |
| C | 269,532 | 1.63 | 1.04 | 0 | 6 |
| *Gender* | | | | | |
| Male | 878,886 | 1.70 | 0.94 | 0 | 6 |
| Female | 183,492 | 1.69 | 0.98 | 0 | 5 |

**Table 5**
Regression of current hole Stableford score.

| Explanatory variable | All | Male | Female |
|---|---|---|---|
| *seq20* | −0.046*** | −0.045*** | −0.040*** |
| | (0.004) | (0.005) | (0.011) |
| *seq02* | −0.028*** | −0.032*** | −0.019* |
| | (0.004) | (0.005) | (0.011) |
| *seq21* | −0.003 | −0.001 | −0.009 |
| | (0.003) | (0.003) | (0.008) |
| *seq12* | 0.000 | 0.000 | −0.008 |
| | (0.003) | (0.003) | (0.008) |
| *seq23* | 0.051*** | 0.051*** | 0.048*** |
| | (0.004) | (0.004) | (0.009) |
| *seq32* | 0.040*** | 0.036*** | 0.059*** |
| | (0.004) | (0.004) | (0.009) |
| *seq24* | 0.075*** | 0.064*** | 0.118*** |
| | (0.012) | (0.013) | (0.027) |
| *seq42* | 0.079*** | 0.073*** | 0.102*** |
| | (0.012) | (0.013) | (0.027) |
| *Constant* | 1.699*** | 1.700*** | 1.695*** |
| | (0.001) | (0.001) | (0.003) |
| $R^2$ | 0.09 | 0.09 | 0.08 |
| N | 944,336 | 781,232 | 163,104 |

Notes: Dependent variable is Stableford score; each column includes controls for hole fixed effects, hole handicap fixed effects, hole pars, and player grades; additionally, column 'All' controls for gender; there are 16 observations per round with at least 2 prior holes; standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

in Table 5 can be used to complete the hypothesis tests set out in Section 2.7. Table 6 shows the results of the one-sided $t$-tests for each sequence pair of interest. Looking first at the difference between the coefficients of *seq20* and *seq02* ($\gamma_0 - \gamma_1$), we find a $t$-ratio of −3.04 which is significant at the 1% level. This is interpreted as evidence of a cold-hand effect since the negative switch in momentum over holes $(j-2)$ and $(j-1)$ is associated with an expected worse score on hole $j$.

The results also show a significant cold-hand effect by the same measure for separate subgroups of men and women, significant at the 5% and 10% levels, respectively. The test conducted on the differences between the coefficients of *seq21* and *seq12* ($\gamma_2 - \gamma_3$) do not show significant evidence of a cold-hand effect for any gender group. Overall, the cold-hand effect appears to be solely driven by the negative psychological momentum stemming from the zero Stableford point score. We cannot draw any firm conclusion as to why the response to net double bogeys (or worse) is so much stronger than the response to net single bogeys. A possible explanation is that a zero-point score will always be perceived strongly as a loss, whereas a one-point score can sometimes be perceived as a reasonable result, such as when it has been salvaged after a terrible tee shot. The stronger emotional response to a loss can affect confidence and decision-making in subsequent play. A more detailed discussion regarding possible mechanisms for the hot and cold hand effects is provided in Section 3.2.

**Table 6**
Response to switches in psychological momentum.

| | Coefficient | | Difference | $t$-ratio |
|---|---|---|---|---|
| | *seq20* | *seq02* | | |
| All | −0.046 | −0.028 | −0.018 | −3.04*** |
| Male | −0.045 | −0.032 | −0.013 | −1.99** |
| Female | −0.040 | −0.019 | −0.021 | −1.44* |
| | *seq21* | *seq12* | | |
| All | −0.003 | 0.000 | −0.003 | −0.73 |
| Male | −0.001 | 0.000 | −0.001 | −0.23 |
| Female | −0.009 | −0.008 | −0.001 | −0.06 |
| | *seq23* | *seq32* | | |
| All | 0.051 | 0.040 | 0.011 | 2.37*** |
| Male | 0.051 | 0.036 | 0.015 | 2.74*** |
| Female | 0.048 | 0.059 | −0.011 | −0.99 |
| | *seq24* | *seq42* | | |
| All | 0.075 | 0.079 | −0.004 | −0.24 |
| Male | 0.064 | 0.073 | −0.009 | −0.50 |
| Female | 0.118 | 0.102 | 0.016 | 0.40 |

Notes: One-sided $t$-tests. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Our first test for the hot hand relates to the difference between the coefficients of *seq23* and *seq32* ($\gamma_4 - \gamma_5$). The $t$-ratio of 2.37 is significant at the 1% level. This is interpreted as evidence of a hot-hand effect since the positive switch in momentum is associated with a better expected score on the current hole. Inspection of the results by subgroup reveals that this result is driven by male players. There is no significant evidence of the hot hand among women.

Lastly, we examine the difference between the coefficients of *seq24* and *seq42* ($\gamma_6 - \gamma_7$). There is no evidence of a significant hot-hand effect for any group. The 4-point score in these pairs, a net eagle, is quite rare. As a result, there are only a small proportion of sample observations where the indicators *seq42* or *seq24* are true. Accordingly, the standard error of the estimated differences between the coefficients is much higher than it is for the other pairs of sequences. It seems likely that the sample size is not big enough to draw a statistically significant conclusion about the impact of a positive switch from 2 to 4 points.

We highlight the point that we conducted a one-sided hypothesis test (right tail) looking for evidence of a hot hand. Another possible test would have been to look for significant evidence of a negative parameter value for ($\gamma_6 - \gamma_7$). Our point estimate for the parameter was in fact negative for the male group and the all players group, however the very small absolute $t$-ratios shown in Table 6 show that we would not have been able to reject a null hypothesis of zero. To round out the discussion of possible mechanisms by which prior holes scores may have a short-term impact on future hole scores, we conjecture that a plausible mechanism by which very good prior scores (such as a rare 4-pointer, which is a net eagle) may cause worse future scores is the loss of emotional control, or break in concentration, that may be caused by the excitement of the rare but positive feat. It could also be caused simply by hubris. However, as noted, we do not have a statistically significant point estimate for this parameter, so we leave this discussion here.

Stroke Play and Stableford offer a slightly different trade off between risk and reward. To check the robustness of our results, we performed the same analysis for a smaller sample of scores relating to Stroke Play, as opposed to Stableford scoring. This was to verify that our findings for hot and cold hand characteristics were not some artifact of the competition format. In short, we re-scored results from Stroke Play as though they had been played under Stableford format and repeated the same style of analysis. The results (not shown) were very similar to the main results given in this paper, suggesting that our findings are not driven by the use of the Stableford scoring format.

### 3.2. Mechanisms

There are several possible mechanisms which could give rise to the hot and cold hand effects described in Section 3.1. These include concepts such as self-confidence, effort and risk aversion. While we are not able to assert what portion of the effects we have measured is attributable to each individual mechanism, the following discussion illustrates how each mechanism may contribute to our findings.

Self-confidence and the related concept of self-efficacy are considered to be important factors contributing to achievement in a wide range of sports (Feltz et al., 2008; Moritz et al., 2000). The role of confidence in golf performance has been accepted as being important in both the academic literature (Rosenqvist & Skans, 2015) and the wider literature on golf teaching resources (Rotella, 2008; Valiante, 2013). Psychological techniques in golf training emphasise elements such as positive thinking and self-talk, whilst learning to suppress fear and negative thoughts.

A drop in self-confidence could contribute to the cold hand effect. The golf swing has been practised thousands of times even by the average club golfer but is executed in less than a second. A good golfer does not consciously coordinate the many mechanical elements of the swing in that fraction of a second, they just clear their head and swing. They rely on the subconscious mind to reproduce what has already been practised. Recent bad play can erode confidence and interfere with this ideal execution of the rehearsed swing. This may be manifested as negative thoughts about the outcome, muscle tension or even an attempt to make a minor modification mid-swing, all of which can lead to an expected worse than average outcome.

If self-confidence is a plausible driver of the cold hand effect, then it is easy to see how the mirror image of the circumstances described above could be a mechanism for the hot hand effect. Following a recent successful hole or good shot, a player may become more confident. Starting from this confident and relaxed state of mind, positive thoughts may result in a small improvement in the probability of a player repeating the previously successful swing(s).

Another mechanism which likely makes a contribution to the cold hand effect is the tendency of some players to give up after a succession of bad holes makes it unlikely that their overall score for the round will be good. This may translate as the player making less effort in regard to simple things like careful alignment and strategic shot selection. Nevertheless, we believe that the contribution of this mechanism on the cold hand effect is dampened in the Stableford format, since the minimum score of zero per hole keeps players competitive for longer.

Other plausible mechanisms behind the hot and cold hand effects are based on a change in the player's level of risk aversion after a recent stretch of good play or bad play. However, it is not immediately obvious whether a change in risk aversion is good or bad for the expected outcome of the next shot. For example, let us assume that the average club player has a favourably biased assessment of their own ability, in particular, they overestimate the probability of them playing a challenging, ambitious shot successfully under pressure. Prospect theory suggests that humans may experience an increase in risk aversion in the domain of gains (Kahneman & Tversky, 1979). Indeed, there is some evidence for this in golf (Pope & Schweitzer, 2011). We can reasonably interpret a positive switch in momentum from success on the prior hole as generating similar feelings to being in the domain of gains, i.e. a player may experience an increase in risk aversion for fear of losing the gains made in recent good play. Increased risk aversion is likely to be good for a player who had a favourably biased assessment of their own ability. In weighing up alternative shot selections and possible outcomes, higher risk aversion will mean applying higher weights to the potential pain of failed outcomes and lead to a shot selection which would actually have a higher expected outcome in a repeat experiment. If true, this would contribute to an observed hot hand effect, since prior good scores could lead to better expected future scores via a temporary increase in risk aversion. Similarly, a mechanism for the cold hand effect could be a decrease in risk aversion after recent bad play which has put the player in a position similar to the domain of losses, i.e., the player becomes less risk averse after bad play and attempts risky or even reckless shots to try and recover the recent loss and, on average, fails to do so.

### 3.3. Individual player characteristics

The results in the previous section provide evidence of a cold-hand effect and a hot-hand effect for men and evidence of a cold-hand effect for women. As noted by Livingston (2012), analysis that considers only the mean impact can mask significant sensitivity at the level of individual players or subgroups of players. For individual players, even the sign (direction) of the response to prior performance may be different to the group average. For example, a player may have an *improved* response on the current hole following a prior bad performance, in which case the behavioural response may be more appropriately labelled "bounce-back" rather than cold hand. Since we have a large number of observations for many individual players (as many as 4000 hole-by-hole observations in some cases) we can derive measures of cold hand and hot hand by individual players.[10] The measures tend not to be statistically significant per player, but when we look at the group of individual results we can gain an understanding of the distribution of player characteristics around the average tendency.

Observations of psychological momentum in sport are typically attributed to an array of factors, such as confidence, positive thinking and positive reinforcement when positive scoring momentum has been observed or a lack of mental toughness or emotional control when negative momentum has been observed. Of course, such attributions are typically made after the fact to fit anecdotal evidence. Similarly, there is a widely held belief that good players have the ability to retain a cool head under pressure, which includes maintaining a calm emotional state after a recent bad hole or good hole in golf.

In sports media, there is a particularly strong emphasis given to the ability to forget the previous bad hole or bad shot to avoid the debilitating effect of negative thinking. For example, former world number one ranked player Rory McIlroy says "you need to be a bit of a goldfish in golf. You need to have a very short memory for the bad stuff".[11] We therefore posit a possible causal relationship between the ability to keep a cool head and being a good golfer (low handicap).

In the first step, we use Eq. (4) for deriving hot and cold hand characteristics for individual players. Regressions are run separately for each player and we filter to include only players for whom we have at least 720 observations (40 rounds of golf). It is similar to the main model expressed in Eq. (3), except that the measure of hot and cold-hand effects will be derived only from the coefficients of two of the sequence pairs used in the main model, i.e. from the coefficients of *seq20*, *seq02*, *seq23* and *seq32*. These were the sequences that showed the most meaningful responses in the group analysis[12]:

$$S_{ij} = \alpha_0 + \gamma_0 seq20_{ij} + \gamma_1 seq02_{ij} + \gamma_2 seq23_{ij} + \gamma_3 seq32_{ij} + \varepsilon_{ij}. \quad (4)$$

We define the following four measures from this equation:

1. Cold = $(\gamma_0 - \gamma_1)/2$
2. Hot = $(\gamma_2 - \gamma_3)$
3. Streaky = $Hot - Cold$
4. Coolhead = $\sqrt{(Hot^2 + Cold^2)}$

[10] The data is anonymised, but individual performances can be grouped by a numerical identifier.

[11] See: https://www.thesun.co.uk/sport/14553893/rory-mcilroy-masters-2021-meltdown.

[12] Note that for an individual player, even with a minimum of 720 observations, there are likely to be only a small number of (or zero) observations of the more rare sequences like *seq24*. It is not practical to derive sensitivity measures for such scenarios for individual players.

**Table 7**
Interpretation of coefficient measures as playing characteristics.

| | Coefficient measure | | |
|---|---|---|---|
| | Negative | Neutral | Positive |
| Cold: $(\gamma_0 - \gamma_1)/2$ | Cold hand | Not cold | Opposite to cold (bounce back) |
| Hot: $(\gamma_2 - \gamma_3)$ | Opposite to hot (hubris) | Not hot | Hot hand |

Notes: Negative, neutral and positive are possible empirical observations of the signed difference between the stated regression coefficients. Combined characteristics: hot hand and cold hand = "streaky"; not hot and not cold = "coolhead".

The Cold measure relates to a 2-shot difference (scores of 0 and 2) whereas the Hot measure relates to a 1-shot difference (scores of 3 and 2). Accordingly, we divide by two in the case of the Cold measure to make the scale of the measure more comparable to that of the Hot measure. We emphasise that hot-hand and cold-hand effects are *not* opposites; a player can have both attributes.

We use the label Streaky for a player showing both hot and cold-hand effects (such as an unusually high incidence of streaks of good holes and streaks of bad holes). Note that the Cold measure is a negative number for a player with the cold-hand effect, so our measure of Streaky will be a positive number for a streaky player with both a hot hand and a cold hand. Lastly, we define the measure Coolhead which will be closest to zero for players who exhibit little or no sensitivity to either prior good or prior bad performance. So, a low Coolhead score is considered good, indicating a player with a cool head. Table 7 is useful to help understand the measures defined above as player characteristics.

In the second step of the analysis, we use Eqs. (5a) and (5b), where $k$ indicates player $k$, to test for a relationship between the average handicap of each player and their characteristic measures derived in the first step.[13] The use of generated regressors means that the standard errors of the estimated coefficients in the second step of the process are likely to be understated (Pagan, 1984). Accordingly, the significance of the estimates in the second step are treated with caution. We run regressions for groups of male and female players separately, the results of which are shown in Table 8.

$$AverageHandicap_k = \alpha_0 + \beta_1 hot_k + \beta_2 cold_k + \varepsilon_k \quad (5a)$$

$$AverageHandicap_k = \alpha_0 + \beta_1 coolhead_k + \beta_2 streaky_k + \varepsilon_k \quad (5b)$$

To highlight the motivation for Eqs. (5a) and (5b), we note that the player characteristics represented by the variables such as $hot_k$ appear on the right-hand side and the measure of player ability, $AverageHandicap_k$, appears on the left. In this way, we can measure the magnitude and direction of the association between the player characteristics and handicap. For example, the variable $hot_k$ will be a positive number for a golfer with a hot hand, so a positive value of $\beta_1$ would indicate that having a hot hand is associated with a higher handicap (being a worse golfer) whereas a negative $\beta_1$ would indicate an association with a lower handicap (better golfer).

The variables $coolhead_k$ and $streaky_k$ are specific interactive variables derived from $hot_k$ and $cold_k$. We have chosen these, rather than the generic ($hot_k \times cold_k$), because they have direct and intuitive interpretations in a sporting context. The streaky player may also be known as the 'confidence player'; one who exhibits both hot streaks and cold streaks. The coolheaded player has a low absolute measure for both hot and cold, which will be reflected in a low value of the $coolhead_k$ interactive variable. As will be seen in the results, we found the most interesting relationships when we examined the interactive variables separately in Eq. (5b).

[13] The average handicap of each player for valid Stableford rounds during the 2 year sample period.

**Table 8**
Regression of individual player characteristics on average handicap.

| Explanatory variable | Eq. (5a) | | Eq. (5b) | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| *Hot* | −0.866 | 5.265 | | |
| | (2.575) | (6.794) | | |
| *Cold* | −9.727** | 6.406 | | |
| | (4.308) | (9.399) | | |
| *Coolhead* | | | 20.822*** | −8.180 |
| | | | (4.116) | (11.613) |
| *Streaky* | | | 0.974 | 0.418 |
| | | | (2.189) | (5.722) |
| *Constant* | 17.129*** | 24.324*** | 14.307*** | 25.385*** |
| | (0.363) | (0.916) | (0.670) | (1.889) |
| $R^2$ | 0.011 | 0.010 | 0.055 | 0.005 |
| N | 458 | 110 | 458 | 110 |

Notes: Dependent variable is average player handicap; there are 458 men and 110 women who satisfy the filter of having played at least 40 rounds in the sample period; standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The regression results show that, for male players only, there is a strong relationship between both Cold and Coolhead and average handicap, significant to at least the 5% level. Recall that the Cold measure is negative for a player exhibiting the cold-hand effect. The coefficient of Cold is negative, which means that a greater absolute cold-hand effect is associated with a higher (worse) average handicap. The Coolhead measure is lower (better) for a player with a cool head. The coefficient of Coolhead is positive, which means that a lower Coolhead measure is associated with a lower (better) average handicap.

The results for the relationship between Coolhead and average handicap are represented graphically in Fig. 1. To help illustrate the magnitude of the slope of the relationship, we calculate that for male players the difference between the median and the lowest Coolhead measure is approximately 0.1116. The product of that difference and the slope coefficient of Coolhead for male players in Table 8 is approximately 2.32, i.e. we expect that the handicap of the coolest-headed player will be just over 2 strokes lower than the handicap of the median player, *ceteris paribus*.

In summary, there is evidence to support the anecdote that the ability to retain a cool head after a recent bad hole or good hole is associated with better golf (a lower handicap) at least for male players, but the relationship is not significant for females. There is no evidence to support the idea that having a hot hand is associated with a lower (or higher) handicap, even though streaks of good holes may often be interpreted as the mark of a champion after they have happened. Finally, whilst there is evidence of the existence of the cold-hand effect for both male and female golfers, it is only in the case of males that it is associated with worse golf (higher handicap) on average.

We cannot draw firm conclusions as to why our evidence tends to show a higher absolute magnitude of emotional responses to prior performance by males than females. A possible contributing mechanism is that females may tend to start with a lower level of self-confidence than men in physical activity (Lirgg, 1991). Our findings suggest that swings in confidence are generally not good for golf, so if there are men who start with (unreasonably) high levels of confidence they may be prone to larger emotional swings, as evidenced by a cold hand effect, when actual performance falls short of expectations.

## 4. Summary and concluding remarks

This paper examines the long-standing conjecture that psychological momentum affects performance. In sporting settings, such analysis is typically complicated by the need to control for changes in the underlying ability of competitors over time. In addition, the existence of strategic momentum (specific to the state of play) may also confound results. Our study addresses these challenges by isolating the effects of psychological momentum in handicapped club golf competitions.

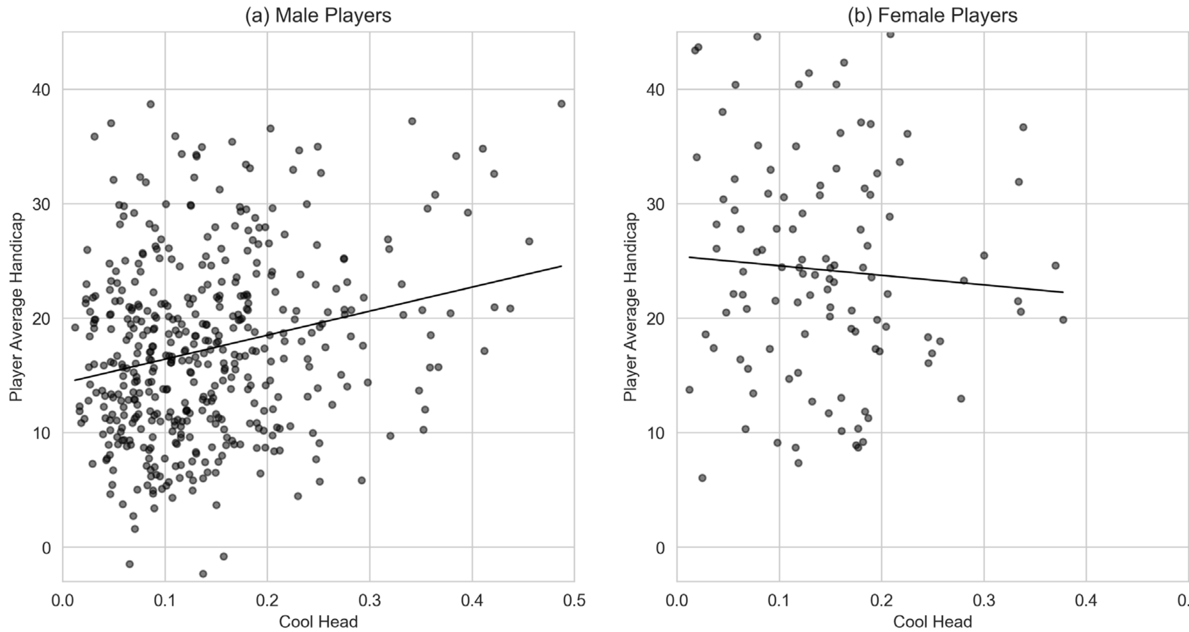


**Fig. 1.** Average handicap versus cool head.

We develop a novel method of isolating the effects of a change in psychological momentum over two-hole sequences. Our study permits the examination of a wider range of individuals than the antecedent literature, which focuses predominately on professional athletes. The presence of both male and female golfers in our data set also enables the examination of gender differences in the response to switches in psychological momentum.

On an aggregate level, we find evidence of a cold-hand effect among both male and female club golfers. This cold-hand effect is driven by larger negative switches in momentum (net double bogeys or worse) and not by smaller negative switches (net bogeys), which are relatively common in club golf. Our findings are consistent with the likes of Arkes (2016), Evans and Crosby (2021) and Livingston (2012) who also find evidence of the cold hand among golfers playing on a variety of developmental and professional tours. We find evidence of the hot-hand effect among male club golfers who experience a positive switch in momentum resulting from a net birdie. Livingston (2012) also finds evidence of the hot hand, but only among the least experienced and least skilled professional golfers. This suggests that the hot-hand effect may diminish as a golfer's ability approaches that of a professional.

We measure the characteristic responses of individual players to switches in psychological momentum and then test for a relationship between the average handicap of a player and each of these characteristics. Male players are more prone to experiencing a cold-hand effect and we found evidence that it is associated with a worse average handicap. We found evidence for men that keeping a cool head is associated with being a better (lower handicap) player, which supports the practice of golfers learning emotional control to improve their average scoring. Evans and Crosby (2021) found that the relationship between keeping a cool head and scoring ability persists through to professional golfers. We find no evidence that any of our four characteristics influence the average handicap of female club golfers. Our work complements and extends prior studies that also report gender-specific responses to a variety of competitive scenarios (Cohen-Zada et al., 2017; Niederle & Vesterlund, 2011).

Overall, our results support the hypothesis that psychological momentum does influence subsequent performance on an aggregate level. Analysis of individual playing characteristics reveals that male golfers in particular would benefit from performance training that incorporates psychological skills, including strategies for controlling emotional responses to success and failure in the short run. Further research could invest the possible mechanisms that give rise to the hot and cold hand effects found in our analysis, including the differences between genders. To do this, a much higher level of granularity of the data would be required, such as data per shot (rather than per hole) with both descriptive and quantitative measures which allowed analysis of elements such as shot selection, risk tolerance and shot-outcome contingent on prior shot-outcomes.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The data that has been used is confidential.

## Appendix

### Illustrative Scorecard for Stableford Competition *(male player)*

Player ID: XXX

Daily Handicap: 6

| Hole Number | Hole Index | Handicap Shots per Hole | Hole Par | Adjusted Par | Gross Score | Stableford Score |
|---|---|---|---|---|---|---|
| 1 | 15 | 0 | 4 | 4 | 4 | 2 |
| 2 | 10 | 0 | 4 | 4 | 4 | 2 |
| 3 | 2 | 1 | 4 | 5 | 4 | 3 |
| 4 | 17 | 0 | 3 | 3 | 5 | 0 |
| 5 | 14 | 0 | 4 | 4 | – | 0 |
| 6 | 8 | 0 | 3 | 3 | 4 | 1 |
| 7 | 3 | 1 | 4 | 5 | 5 | 2 |
| 8 | 12 | 0 | 5 | 5 | 6 | 1 |

| Hole Number | Hole Index | Handicap Shots per Hole | Hole Par | Adjusted Par | Gross Score | Stableford Score |
|---|---|---|---|---|---|---|
| 9 | 6 | 1 | 4 | 5 | 4 | 3 |
| 10 | 4 | 1 | 4 | 5 | 4 | 3 |
| 11 | 11 | 0 | 5 | 5 | 5 | 2 |
| 12 | 5 | 1 | 4 | 5 | 3 | 4 |
| 13 | 18 | 0 | 4 | 4 | 3 | 3 |
| 14 | 16 | 0 | 3 | 3 | 3 | 2 |
| 15 | 13 | 0 | 5 | 5 | 9 | 0 |
| 16 | 9 | 0 | 3 | 3 | 4 | 1 |
| 17 | 1 | 1 | 4 | 5 | 6 | 1 |
| 18 | 7 | 0 | 4 | 4 | 4 | 2 |
| | | 6 | 71 | | | 32 |

The aggregate Stableford score would be 36 points for a person who has 'played to their handicap', i.e., equivalent to 2 points per hole.

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