Running Head: Eye dominance and hand preference in golf

Laterality and performance: Are golfers learning to play backwards?

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Abstract

When using a bimanual tool to strike an object, most people place their preferred hand closer to the striking end. In sports, a player is deemed to adopt a 'right- or left-handed' stance depending on the hand that is lower on the club or bat. Research has suggested there is an advantage in going against this convention by placing the preferred hand at the top in a 'reversed-stance'. This study aimed to establish if the reversed-stance advantage exists in golf, whether it is underpinned by the preferred hand or dominant eye, and why players might adopt such a stance. We tested hand preference, eye dominance, and full swing stance in 150 golfers (30 for each handicap category) and conducted follow-up interviews with 12 reversed-stance players. Professional or category 1 golfers were 21.5 times more likely to adopt a reversed-stance. The advantage could not be explained by ambidexterity or the dominant eye but could be explained by the position of the preferred hand. Reversed-stance players cited a variety of reasons for adopting it and were more likely to display a left-hand preference. Findings offer initial evidence of a reversed-stance advantage in golf and can inform work identifying its origins and mechanisms.

Keywords: Motor learning; expertise; handedness; ocular dominance; bimanual tool use

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The majority of people consistently use a preferred hand when conducting everyday tasks, with around 90% preferring their right hand (Hardyck & Petrinovich, 1977; Raymond et al., 1996). These lateralised behaviours influence the way in which humans execute many different motor skills, including bimanual tasks. When executing bimanual striking tasks such as using an axe or hitting a baseball, the grip and stance depend on the preferred hand. Conventionally in such tasks, the preferred hand of an individual will be placed closer to the striking end of the tool. For example, in golf, a player is referred to as being right-handed if the right hand is below the left on the grip and the left shoulder is facing the target; or left-handed if the left hand is below the right on the grip and the right shoulder is facing the target. Sporting definitions are so well established that, while not being in the final inventory due to lack of familiarity for non-sporting users, the position of the bottom hand in cricket and golf stances were tested in the original development of the Edinburgh Handedness Inventory (EHI; Oldfield, 1971). These sporting tasks are an excellent vehicle for examining the development of motor expertise in bimanual tasks by offering highly competitive environments where small technical advantages can offer significant benefits.

The subject of laterality in the development of expertise in sport has seen considerable attention in the literature (Loffing et al., 2016). The majority of this research has focused on over-representation of left-handed players in interactive sports (Loffing et al., 2010; Wood & Aggleton, 1989). However, while commonly used in sport, definitions of right and left-handed players have not accounted for whether a player has a preference for the right- or left-hand in other everyday tasks such as writing or throwing, but instead focus on the manner in which the sport is played (Mann et al., 2016). Most of the population will adopt a stance that matches their hand dominance (i.e., throw and write with the right hand and play in a right-handed stance). However, a small proportion of people defy this and play a sport with their preferred hand at the top of the grip. For example, a right-hand preferred person who places their right hand at the top of the grip on the golf club and swings with their right shoulder closer to the target would commonly be referred to as a left-handed player (Figure 1C; this phenomenon has previously been defined as *reversed-stance*; Mann et al., 2016).

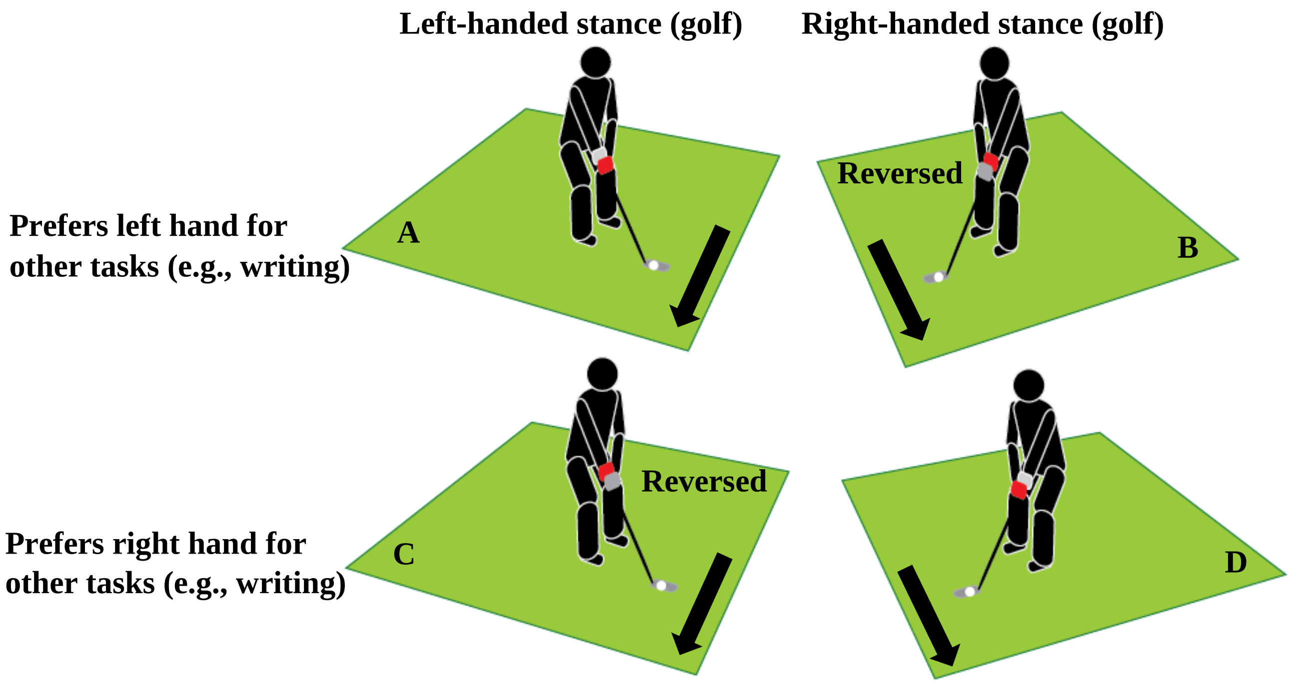

Fig 1. The arrows show the direction of play. The red hand shows the hand that is preferred in other everyday tasks. (A) shows a traditional left-handed stance (i.e., prefers left-hand for other tasks and plays golf in left-handed stance). (B) shows reversed right-handed stance (someone who prefers their left-hand for other tasks but adopts a right-handed golf stance). (C) shows reversed left-handed stance (someone who prefers their right-hand for other tasks but adopts a left-handed golf stance, like Phil Mickelson). (D) shows a traditional right-handed stance (i.e., prefers right-hand for other tasks and plays golf in right-handed stance). Note players do not (or at least extremely rarely) place the hand from the front shoulder below the hand from the back shoulder on the grip due to it making it almost biomechanically impossible to execute a full swing.

To address this omission from the laterality literature, Mann, Runswick and Allen (2016) investigated whether, in the bimanual hitting task of cricket batting, the players who adopted a left-handed stance actually preferred their left-hand in other tasks. The results of this study showed a large over-representation of batters adopting a left-handed stance in elite cricket. This over representation could not be explained by a frequency dependent advantage for left-handed players (Brooks et al., 2004) or mixed handedness (McManus et al., 1999). Instead, results showed that a large proportion of these players actually preferred their right-hand in other activities (e.g., writing and throwing) so could be described as right-handed people who adopt a left-handed stance. The authors postulated that a technical biomechanical advantage may be gained, not by adopting a left-handed stance, but by placing the hand preferred for other activities at the top of the grip, contradicting convention, and years of coaching literature (Mann et al., 2016). This was referred to as a *reversed-stance advantage.* The advantage would still be available to a player who prefers their left hand in other activities adopting a right-handed stance, however the number of left-handed people (approximately 10% of the population) severely limits the number of this type of reversed-stance players. Numerous notable examples of such players who had been some of the best in cricket's history were identified. The authors suggested this effect could occur in other sports involving bimanual striking tasks (Mann et al., 2016).

The reversed-stance advantage has since been replicated in baseball. Again a biomechanical advantage of a strong top-hand was postulated as an explanation (Mann et al., 2017). It is possible that a similar advantage could be at play in golf. Four men have won one of golf's major championships using a left-handed stance (here we are referring to the full swing rather than putting). Of these men, three prefer their right-hand when writing; Phil Mickelson (ironically nicknamed 'Lefty'), Mike Weir and Sir Bob Charles, with only Bubba Watson preferring his left-hand for other everyday activities. Three-time major winner Jordan

Spieth throws and shoots left-handed but plays golf in a right-handed stance. The findings of Mann et al., (2016) and Mann et al., (2017) would suggest that it is possible these players enjoy(ed) some kind of advantage from playing in a reversed-stance.

There has been a significant body of biomechanical and coaching literature that has performed detailed technical analyses of the golf swing (see Toms, 2018). While current golf literature does not suggest using a reversed-stance, it does uncover two possible explanations for why a reversed-stance advantage could occur. Firstly, a reversed-stance player may enjoy an advantage from the position of the hand they prefer for other activities (e.g., writing). It is typically suggested that the top hand (conventionally the non-preferred hand for writing) is responsible for controlling the path of the golf swing and grips the club more tightly throughout the swing (Broker & Ramey, 2007; Nicklaus & Bowden, 1984). In a reversed-stance player, this top hand would be the stronger preferred hand, and would both grip the club more tightly and avoid an overactive bottom hand.

Secondly, the position of the dominant eye is regarded as being a factor in the successful execution of a golf swing. Jack Nicklaus, a player who adopted a right-handed stance and the most successful in major championship history, describes his left eye as his ‘master eye’ and the one through which he predominantly sees the ball (Nicklaus & Bowden, 2005). Empirical work (focusing on golf-putting rather than the full swing) has tentatively suggested a performance benefit of aligning the ball with the dominant eye (Sugiyama & Lee, 2005) and that eye dominance in the stance may be different to that measured outside the golfing context (Dalton et al., 2015). Strong hand preference increases the chances of congruent eye dominance (Annett, 2002), especially in left–sided individuals (McManus et al., 1999). Therefore, if a golfer is playing in a reversed-stance, they are more likely to have a dominant front eye, and this could potentially convey an advantage in the swing.

The position of the hand that is preferred for everyday activities or the dominant eye may offer answers regarding the mechanism that underpins the reversed-stance advantage, but they do not explain why one would adopt these stances in the first place. There are several possible reasons for why this may occur. Mann et al., (2016) hypothesised that having the preferred hand closer to the striking end of the tool may offer a short-term advantage in the earlier stages of learning. Whereas the preferred hand being further from the striking end may be advantageous for longer term performance. Secondly, a small proportion of the population display ambidexterity or mixed handedness where they write and throw with different hands (McManus et al., 1999; Peters & Servos, 1989). People with mixed-handedness could plausibly play golf either way around and adopt a kind of reversed-stance. Finally, previous work has cited anecdotal reports from famous players in a variety of sports that offer other explanations, such as Mike Hussey copying his favourite player in cricket (Hussey, 2013), or Phil Mickelson mirroring his father's swing in golf (Phil Mickelson PGA Tour Profile, 2021). No research to date has explored the origins of the reversed-stance.

The aim of this study was, therefore, to determine whether the reversed-stance advantage in the development of expertise in bimanual hitting extends to the sport of golf, whether this advantage is due to the position of the hand that is preferred for everyday tasks and/or the dominant eye, and finally to establish why players developed a reversed-stance technique in the first place. We tested the hand preference, eye dominance, and the golf stance of 150 golfers sampled from professional players and the five handicap CONGU categories in the UK. We hypothesised that a reversed-stance (preferred hand at the top of the grip; Figure 1) would offer a significant advantage to golfers who play in both a left or right-handed stance. This advantage would be displayed by an over representation of reversed-stance players in the low handicap category (this included the professional golfers) and would be underpinned by an advantage gained either from the position of the dominant eye and/or the position of the preferred hand during the swing. We then conducted interviews with 12 reversed-stance golfers to explore their experience in playing golf in this unconventional fashion, the reasons for it, and their perception of advantages that may be gained. Following the interviews, we revisited ambidexterity as a possible mechanism underpinning the reversed-stance advantage.

Method

Design

This study employed a mixed-methods design (Creswell & Plano Clark, 2010) to investigate the occurrence of reversed handedness in golf and offer a preliminary exploration into why this could occur. The first phase was a quantitative analysis to investigate the occurrence of reversed-stance players at different skill levels and the relationship of skill level with eye and hand dominance. The second phase utilised qualitative methods and individually interviewed a sub-sample of twelve of the original participants who displayed a reversed-stance. The interviews further investigated how they started playing this way, perceptions of performance benefits and how they play other sports.

Participants

One hundred and fifty golfers participated in the study. The participants were split according to handicap category with 30 participants in each of the 5 handicap categories (category 1 = handicap of 5 or less; category 2 = handicap of 6 to 12 inclusive; category 3 = handicap of 13 to 20 inclusive; category 4 = handicap of 21 to 28 inclusive; category 5 = handicap of 29 to 36 inclusive). The category one group included golfers playing on the TP tour, for the England Men’s A Squad, club professionals, and club golfers. The other four categories included club golfers recruited from an English golf club. The average age of the participant was 48 years (standard deviation = 19 and range from 18 to 88 years). After participants had completed the testing, all the reversed-stance players (n=12) volunteered to participate in a follow-up interview. The experimental procedure conformed to the ethical standards of the Declaration of Helsinki and was approved by the Faculty Research Ethics Panel of Anglia Ruskin University, with participants informed about the nature of the study and signing informed consent forms prior to testing.

Procedure

Hand Preference

Hand preference was determined by asking participants to fill out the Edinburgh Handedness Inventory Form (EHI; Oldfield, 1971). This validated questionnaire provides a measure of handedness by testing the hand used during ten activities of daily living (e.g., writing; throwing; using a toothbrush; and using a spoon). For each of the ten activities, participants rated whether they use their right or left hand for that activity on a five-point scale from always right to always left. According to the questionnaire guidelines, we scored always right as 2, always left as 0, with increments of 0.5 between, meaning mixed-handedness scored 1. Participants whose average score across all ten tasks was greater than one were classified as right-hand preferred, those whose score was below one were classified as left-hand preferred, and a score equal to one were classified as mixed preference. We classified golf stance by the type of clubs used (right-hand or left-hand). The clubs used are dictated by the stance. Asking about club type is a more accessible question for golfers that removes the need to describe shoulder and hand position (i.e., you cannot hit in a right-handed club with a left-handed stance).

Eye Dominance

Eye dominance can vary depending on how it is tested and depends on factors such as (a) horizontal gaze angle (i.e. eye dominance switches to the side of target presentation as a function of eccentricity; Khan & Crawford, 2001), (b) viewing distance used whilst testing (Ho et al., 2018), and (c) may differ in a golf stance from generic measures (Dalton et al., 2015).

Carey and Hutchinson (2013) have shown that this effect was modulated by the hand used to carry out the task, suggesting some sort of sensorimotor relationship between hand and eye dominance. Therefore, ocular dominance was measured using a chart previously used in golf by Dalton et al. (2015) and was recorded using both hands. The chart was scaled for use at 3m so the difference between adjacent lines is equal to 1 prism dioptre. Participants were therefore asked to point (with both hands interlinked) towards the cross in the centre of the chart whilst viewing binocularly from 3m. This technique allows binocular vision to be maintained and should be used in tests for eye dominance (Laby & Kirschen, 2011). Each eye was then covered in turn and the participants indicated where their fingers were pointing on the chart when each eye was covered. Values to the left of the cross were considered negative and to the right of the cross positive. The individual scores from each eye were summed to provide a quantitative eye dominance score. Ocular dominance (OD) was then classified according to the following criteria: Strong right dominance OD > 4, Weak right dominance 2 ≤ OD ≤ 4, No dominance -2 < OD < 2, Weak left dominance -4 ≥ OD ≤ -2, Strong left dominance OD < -4. Positive scores indicated a right ocular dominance and negative scores a left ocular dominance.

Interviews

The semi-structured interviews consisted of four core questions. Two open-ended to investigate the reasons behind the player adopting a reversed-stance and whether the player perceived any possible advantage and the reason for this. Two more questions invited participants to describe whether they had ever tried playing conventionally and how they play other sports.

Analytic Strategy

Category 1 and professional players (i.e., players who have reached a high-performance level) were used as the reference group (n = 30) compared against all other categories (i.e., players who play at lower levels; see Mann et al., 2016). Within each group players were classified as either conventional or reversed-stance regardless of whether they chose a right or left-handed stance. First, an independent samples t-tests were used to compare EHI scores between reversed and conventional players. Next one-way ANOVA was used to assess the effect of handicap categories on EHI scores. Bonferroni corrections were used where multiple-comparisons were being made to avoid type-1 error (McLaughlin & Sainani, 2014). Cohen's d was used as an effect size measure for t-test analysis and partial eta squared (ηp2) for ANOVA. Alpha value was set at p = .05.

Eye Dominance and Hand Preference

The combination of hand preference and eye dominance was defined as it has been in previous literature by using the measures of overall eye dominance and hand-preference, not the golf stance (Annett, 2002; McManus et al., 1999). Players were defined as having aligned (e.g. left eye dominant, left-handed preference) or crossed (e.g. left eye dominant, right-handed preference) eye dominance. Ambidextrous or mixed eye dominance subjects were assumed to be not crossed. A reversed-stance player who has aligned eye dominance and hand preference would have the dominant eye closest to the target. Chi-squared was used to analyse how the proportions of reversed-stance players and crossed eye-hand dominance players differed across groups. Odds ratios (OR) were then calculated to give an effect size.

Interviews

Due to the lack of previous work in the area we were not able to generate categories for a content analysis based on previous literature. Therefore, to analyse the follow-up interviews, we used a blended approach (Brough, 2018; Brough et al., 2010) where we first needed to analyse interview content inductively to produce themes that could then be used for categories in a content analysis (e.g. Calmeiro & Tenenbaum, 2011). Therefore we firstly conducted a thematic analysis as outlined by Braun and Clarke (2006) to generate themes from the data. In order to become familiar with the data the transcripts were first read and reread by the lead researcher (OR) with initial observations noted. Next features of the data were labelled and compiled in order to allow for themes to be identified. Codes were then organised into themes. Themes were then reviewed, combined, and then final themes defined. These themes were then used to develop a categorisation matrix.

For content analysis transcripts were broken into clauses and each clause was coded based on the themes generated. This process was conducted for each key question and participants were not limited to single codes per questions. For example, a participant may mention both power and accuracy when discussing performance advantages. To ensure inter-rater reliability, the data was coded by the lead researcher (OR) and by an experienced qualitative researcher who was not part of this study researcher to reduce any possible bias (Davey et al., 2010). The analysis was run using number of statements assigned to each possible code in each question (seventeen possible codes) for all twelve participants (a total of 204 ratings) to determine if there was an agreement in coding between the two researchers. Raters agreed on 92% of ratings and Cohen's kappa analysis indicated that there was a substantial agreement between the two researchers, $k = 0.77$, $p < .01$ (McHugh, 2012). The data in discrepancy was discussed and both coders came to an agreement. Since the purpose of the interviews was to explore possible reasons for adopting a reversed-stance, only means and standard deviations were calculated for content analysis.

Post-Hoc Ambidexterity

Following the findings from the planned interviews, an index of ambidexterity was calculated for each player utilising data from the EHI that was converted to show ambidexterity independent of hand preference. This was achieved by calculating $= ABS(1 - (ABS(1 - EHI)))$ where ABS is the absolute value and EHI is the Edinburgh Handedness Inventory score. This meant zero was equal to no ambidexterity (e.g., displayed full right hand or left-hand preference, this would be a 0 or 2 on EHI) and 1 was equal to complete mixed handedness (displayed mixed handedness, this would be a 1 on EHI). First, independent samples t-tests were used to compare index of ambidexterity between reversed and conventional players. Next a one-way ANOVA was used to assess the effect of handicap categories on ambidexterity. Bonferroni corrections were used where multiple-comparisons were being made to avoid type-1 error (McLaughlin & Sainani, 2014). Cohen's d was used as an effect size measure for t-test analysis and partial eta squared (η_p^2) for ANOVA. Alpha value was set at p = .05.

Results

Hand Preference

The number of players in each of the four stance types and the descriptive statistics for the EHI, index of ambidexterity, and eye dominance can be found in Table 1. There was a significant effect of handicap category on EHI scores (F = 4.31, p = 0.003, η_p^2 = 0.106). Post-hoc comparisons showed category 1/pro players (1.56 ± 0.70) to be significantly less right-handed than category 3 (1.89 ± 0.38, p = 0.03, d = 0.65) and category 4 players (1.99 ± 0.03, p = 0.001, d = 0.89).

Table 1. Count data the different combination of stance and hand-reference and descriptive statistics of hand preference, ambidexterity, and eye dominance across each handicap category (see Figure 1 for an explanation of different stances). Note categories 2-5 are combined for odds ratio analysis.

	Pro and Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**
N	30	30	30	30	30
Mean Age in Years (SD)	35 (10)	52 (14)	67 (15)	58 (18)	47 (18)
Conventional Right-handed Stance (%)	21 (70)	29 (97)	29 (97)	30 (100)	27 (90)
Reversed Right-handed Stance (%)	7 (23)	1 (3)	1 (3)	0 (0)	0 (0)
Conventional Left-handed Stance (%)	0 (0)	0 (0)	0 (0)	0 (0)	2 (7)
Reversed Left-handed Stance (%)	2 (7)	0 (0)	0 (0)	0 (0)	1 (3)
Mean EHI Score (SD)*	1.56 (0.68)	1.84 (0.37)	1.89 (0.21)	1.99 (0.02)	1.84 (0.48)
Mean Index of Ambidexterity (SD)**	0.15 (0.24)	0.10 (0.15)	0.11 (0.21)	0.01 (0.03)	0.03 (0.07)
Mean Eye Dominance Score (SD)***	0.25 (5.13)	0.1 (3.80)	1.4 (5.24)	0.0 (3.71)	0.03 (2.83)

* Always left = 0; mixed = 1; always right = 2

** 0 = strong hand preference; 1 = mixed

*** Strong right dominance $OD > 4$, Weak right dominance $2 \leq OD \leq 4$, No dominance $-2 < OD < 2$, Weak left dominance $-4 \geq OD \leq -2$, Strong left dominance $OD < -4$. Positive scores indicated a right ocular dominance and negative scores a left ocular dominance.

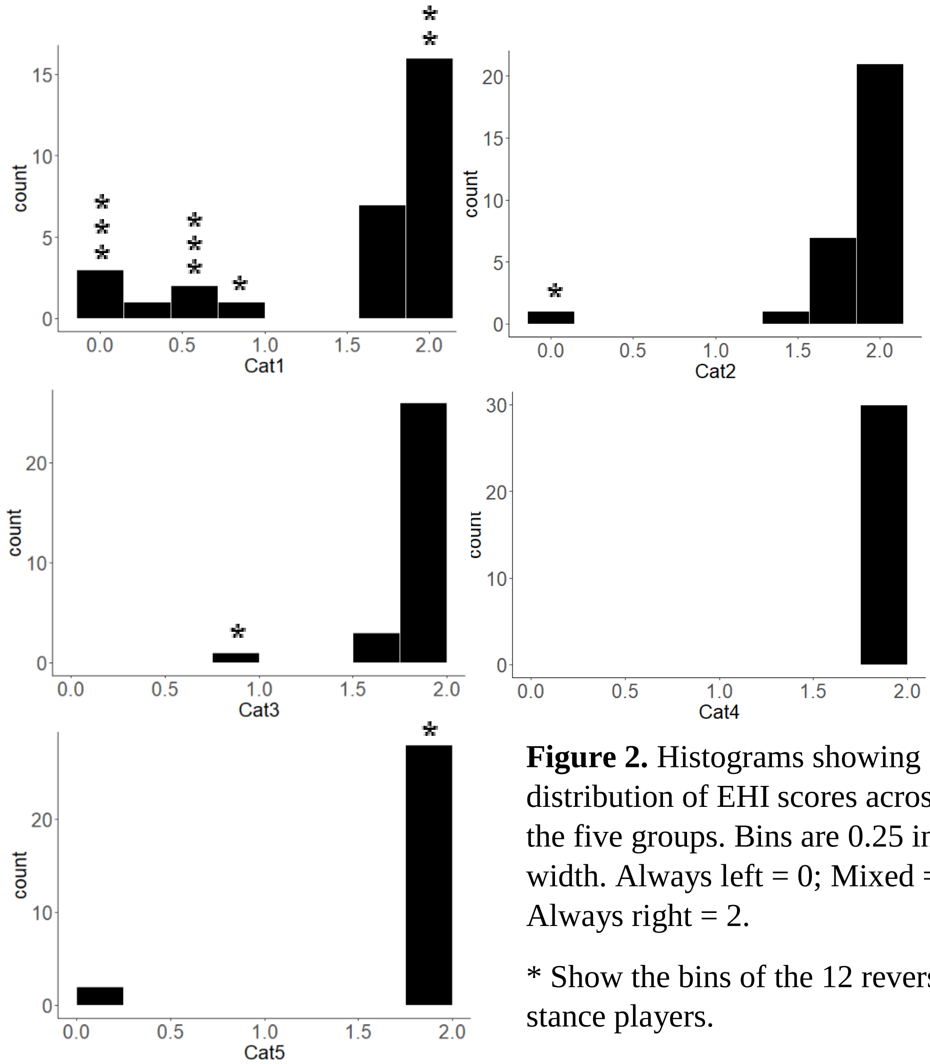

Figure 2. Histograms showing distribution of EHI scores across the five groups. Bins are 0.25 in width. Always left = 0; Mixed = 1; Always right = 2.

* Show the bins of the 12 reversed-stance players.

Reversed vs. Conventional Stance

Conventional players (1.91 ± 0.25) scored as more right-handed on the EHI than reversed players (0.78 ± 0.78; $t = 11.61$, $p < 0.01$, $d = 3.49$). Professional and category 1 golfers were 21.5 times more likely to be playing in a reversed-stance than players in higher handicap categories ($\chi^2 = 24.6$, $p = .0001$; $OR = 21.5$, $95\%\ CI = 4.3$-107.9). 27.6% of players in professional (13.8%) and cateogry 1 (13.8%) played in a reversed-stance compared to 3.33% in categories 2 and 5 and 0% in categories 3 and 4.

Eye Dominance

Our group of professional and category 1 golfers were no more likely to have crossed eye dominance than players in higher handicap categories (χ^2 = 1.713, *p* = .191; *OR* = 1.6, *95% CI* = 0.6-4.3).

Interviews

Thematic Analysis

Themes were generated from the telephone interview data from the 12 reversed-stance players primarily for the purpose of inductively creating codes for the content analysis. Table 2 shows the themes identified in the telephone interviews and example quotes.

Content Analysis

Figure 3 shows the results of the content analysis based on the codes developed from the thematic analysis. Golfers showed a variety of reasons for using the reversed-stance and different opinions on whether it confers an advantage. When asked if they had tried to play both ways, six of the golfers suggested they had and the other six suggested that had not. When asked how they play other sports seven golfers said they play the conventional stance (opposite to their golf stance), four suggested they play sports in a variety of ways, some conventional, some reversed and only one suggested they playing other sports reversed too.

Table 2 – Themes that emerge from the follow-up interviews and example quotes.

Question	Theme	Example Quote
Why do golfers start to play reversed?	Equipment	I am left-handed but learnt to play with someone else’s clubs so play golf right-handed
	Feel	It just felt more natural this way
	Ambidexterity	I’m ambidextrous so tried it both ways. I preferred reversed
	Performance advantage	I hit it further
	Just did	I don’t know – I just did
Do reversed golfers feel they have a performance advantage and why?	No	Not Really
	Don’t Know	Not Sure
	Strong hand position	I like my strong hand at the top of the club
	Accuracy	Yes, for me – I hit it straighter this way
	Distance	Yes, because I hit it further
	Feel	It just felt more natural this way
	Yes - unspecified	It is for me – my handicap came down really quickly once I changed the way I played
Have reversed golfers tried both ways?	Yes	Tried it but didn’t like it
	No	No
How do reversed golfers play other sports?	Conventionally	Conventional, everything else I play left
	Reversed	Mostly reversed
	Mixed	I can use both hands so ended up playing some sports right-handed and others left-handed

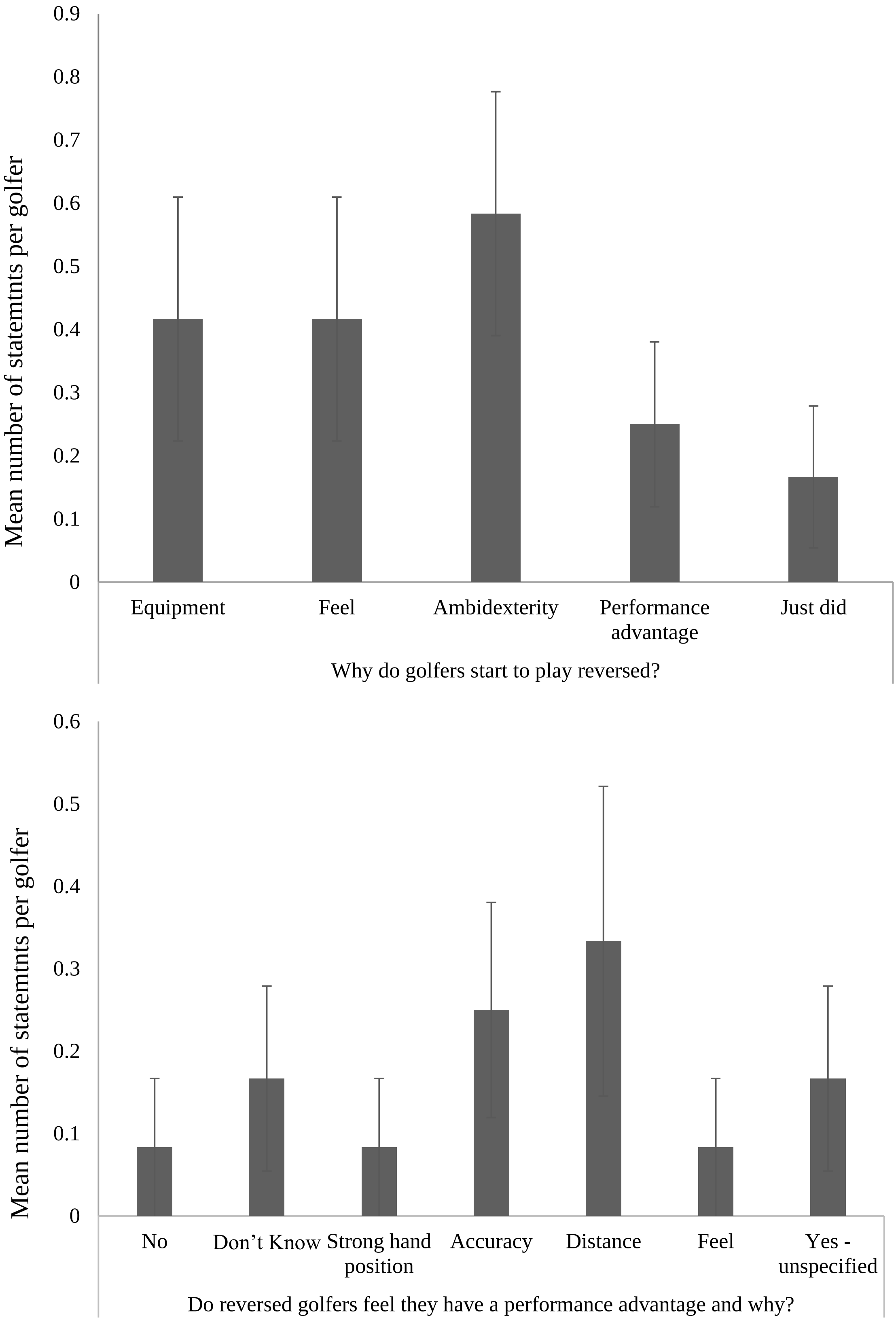

Fig 3. Mean (SE) number of statements mentioned per golfer in each category for (A) why they play reversed and (B) whether or not it has an advantage.

Ambidexterity

There was no significant difference in index of ambidexterity between reversed-stance (0.18 ± 0.25) and conventional (0.07 ± 0.18) golfers (t = 1.317, p = 0.22, d = 0.50). There was, however, a significant main effect for handicap category on index of ambidexterity (F = 4.06, $p = 0.004$, η_p^2 = 0.10). Post-hoc comparisons showed significant differences in ambidexterity between category 1 (0.15 ± 0.24) and category 4 (0.01 ± 0.03, p = 0.01, d = 0.86) and category 1 (0.15 ± 0.24) and category 5 (0.03 ± 0.07, p = 0.04, d = 0.69).

Discussion

In this study we tested the hand preference and eye dominance of golfers of various levels of ability to establish whether playing in a reversed-stance provides an advantage in the development of skill. We predicted that highly skilled golfers (handicaps equal or better than 5) would be more likely to adopt a reversed-stance with the preferred hand at the top of the grip, rather than in the traditional stance with the preferred hand below on the grip. We found a significant over-representation of category one and professional golfers adopting a reversed-stance and that they did so for a wide variety of reasons. Findings extend the evidence found in other bimanual hitting actions such as cricket (Mann et al., 2016) and baseball (Mann et al., 2017), and suggest some golfers may have also enjoyed a reversed-stance advantage.

When investigating the mechanisms underpinning the reversed-stance advantage, we found that the position of the dominant eye in reversed-stance players did not differ from the conventional players. Therefore, the dominant eye does not explain the over-representation of the reversed-stance in higher skill groups. This finding mirrors that of Mann et al (2016) in cricket and suggests that Nicklaus's idea of his 'master-eye' may not be a performance advantage in this larger sample of players (Nicklaus & Bowden, 2005). However, the idea that each hand performs a specific task within the swing may be pertinent (Nicklaus & Bowden,1984). The position of the preferred hand did explain the over representation of reversed-stance players in the more skilled group. An equal number of professional and category 1 players displayed a reversed-stance. This suggests a reversed-stance may not differentiate players at the highest level but may be helpful in reaching that category of player. There could be an advantage available to players who learn to play golf in a stance opposite to what would be traditionally expected from their hand preference.

There was a significant effect of handicap category on both the index of ambidexterity and handedness. Skilled players were more ambidextrous, and both more skilled players and reversed-stance players were more likely to display a left-handed preference in day-today activities. However, the reversed-stance players were no more ambidextrous than conventional players. This suggests that ambidexterity does not explain why players adopt a reversed-stance, but left-handedness could. Previous work in professional basketball has shown that extensive practice in a sport involving bimanual actions may lead to an increase in ambidexterity as measured using the EHI (Stöckel & Weigelt, 2012; Stöckel and Vater, 2014). Therefore, the extensive time spent playing golf that professional and category one players have engaged in could increase an individual's index of ambidexterity due to the time spent using both hands on the task. This would occur regardless of the stance adopted (Marcori, Monteiro & Okazaki, 2019). This, however, would not explain why the reversed-stance players are more likely to display a preference for their left-hand in day-to-day tasks independently from ambidexterity.

In follow-up interviews, we found various reasons for players adopting a reversed-stance, including ambidexterity and the combination of hand preference and available equipment. While few of the players suggested that they had adopted a reversed-stance because they thought it would lead to performance advantages, the majority suggested that their reversed-stance had led to increased distance, accuracy, or feel. Despite findings in other sports (Mann et al., 2016; Mann et al., 2017), only one reversed-stance player played other sports in the same way. This suggests the origins of the reversed-stance for individual players may be sport-specific, not related to the perceived performance advantages that resulted.

Nine of the twelve reversed-stance players in this study either displayed a left-hand preference or were ambidextrous. This suggests it may be more likely, or perhaps easier, for a player with left-handed preference to adopt a reversed-stance. For example, it is possible that players with a left-handed preference in other activities adopted a reversed-stance due to a necessity where only right-handed clubs were available at the early stages of learning. This was the case for three players here, but also for one player with a right-handed preference who used his fathers left-handed clubs. Six of the twelve reversed-stance players had tried to play both ways and *chosen* a reversed stance, the other six had not. Trying a reversed stance later in skill development would be extreme and mean sacrificing potentially years of skill development for what are, at this point, unknown longer-term benefits. The interviews conducted here could be used to inform broader investigation of reasons that players adopt different types of stances. Future research should utilise the well-developed methods in the biomechanical analysis of the golf swing to objectively investigate the perceived advantages cited by the players. The observation that the more skilled and reversed-stance players are considerably younger also raises the possibility that older players in the other groups had less opportunity to try a different stance due to availability or expense of equipment.

Coaching and biomechanical literature to date has not accounted for the presence of reversed-stance players. In fact, many studies select only ‘right-handed’ golfers without considering whether these players have a preferred right or left hand (Joyce et al., 2013; MacKenzie & Boucher, 2017; Zou et al., 2017). Biomechanical analysis of the golf swing conducted in skilled performers has identified the presence of stronger grip pressure in the top-hand (Broker & Ramey, 2007). This supports the explanation that the over-representation of reversed-stance players found in the lower handicap and professional golfers may be due to an advantage gained from positioning the preferred hand at the top of the grip. However, these previous findings could also be explained by the unknown presence of reversed-stance players in the sample. Previous studies, which have investigated the golf swing using highly skilled players, are likely to have been impacted by a proportion of the sample that play in a reversed-stance.

The findings presented raise an interesting question. Why, in a game that first formalised its rules in 1744 (Green, 1987) and is now a highly lucrative industry, do most golfers learn to play the game in a stance that may limit the standard of play and seems counter intuitive to key coaching points? It is possible that having the preferred hand closer to the striking end of the club offers an easier way to strike the ball when first learning the game, but this does not convey long-term advantages in the development of highly skilled performance (Mann et al., 2016). When learners move through the multiple stages of learning (Newell, 1986), it may be easier to freeze degrees of freedom and gain more control earlier in the process by decreasing the moment arm of the tool. However, as skill develops having a strong grip further from the striking end would increase power due to the main pivot being further from the striking end of the club and increase control as the top hand guides the swing as the reversed-stance players identified in the interviews. However, evidence for this approach to motor learning is mixed, particularly in relation to freezing degrees of freedom in discrete skills that involve a combination of accuracy and velocity like the golf swing (Guimarães et al., 2020). Extending the questions around the specificity of the reversed-stance by investigating a combination of sports involving bimanual actions (only one reversed-stance player in this sample played other sports in the same way) may be an interesting avenue to uncover why the reversed stance may occur in different activities.

The cross-sectional approach of this study has identified an over representation of reversed-stance players in the most skilled group but cannot offer a robust answer to the questions on long-term benefits and the skill acquisition process, and raises several questions about the origins and underpinning of the reversed-stance advantage. We have, however, discounted eye-dominance as an underpinning factor meaning that, due to the simplicity of a handedness survey and playing stance, measurement of a large population of players is now possible remotely. Future work could replicate these findings in a sizeable sample of players with the potential to track players across stages of development. These methods would overcome the large effect individual players with reversed-stances could have had on our data and the possibility that the overrepresentation of skilled reversed-stance players in our sample does not represent the wider population of golfers. Furthermore, here we have focused on the full-swing. Ocular dominance and handedness would also be a relevant area of investigation in golf putting, a very different skill within the game where hand and eye dominance may offer different advantages. Future work in this area could both benefit sporting performance and offer insight into the development of bimanual tool use.

We have built on previous work from other bimanual sports to show that there may also be a reversed-stance advantage in golf and that it may occur more frequently in individuals with a left-hand preference in other day-to-day activities. We have also offered the first preliminary exploration into why players may adopt such a stance. Findings support those from cricket in that the reversed-stance advantage is not underpinned by the position of the dominant eye. Instead, there may be an advantage to playing golf with a reversed-stance due to the placement of the preferred hand at the top of the club. This could have a significant effect on how the game is taught and played.

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