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Putts that get missed on the right: Investigating lateralized attentional biases and the nature of putting errors in golf

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Abstract

Although the effects of lateral biases in visual attention (''pseudoneglect'') have been examined in real-world settings, this phenomenon has yet to be considered within the realm of sporting performance. In the present study, we investigated the effects of pseudoneglect on putting errors in golf. Novice golfers (n = 30) performed 90 putting trials followed by a series of pseudoneglect tasks: requiring participants to bisect lines manually and with a biomechanical bisection tool. All pseudoneglect measures were performed with both the left and right hands. Results demonstrated a leftward bias for all the pseudoneglect tasks, and a rightward bias for putting error. Moreover, the results revealed that individuals who bisected lines to the left on the Bisection Tool (the typical class of pseudoneglect error for humans) with the left hand (the hand that typically produces the greatest pseudoneglect bias) displayed significantly smaller rightward putting errors. Moreover, these individuals also holed more putts. No other pseudoneglect tasks were shown to impact on putting performance. Our findings suggest that lateralized attentional biases have a significant effect on sport performance; they appear to influence a wide range of precision-based sports (e.g. shooting, archery). Findings are also discussed in terms of the processes that are likely to be involved in this effect.

Keywords: *Pseudoneglect, sport performance, line bisection, bisection tool*

Introduction

Researchers studying the psychological processes involved in the performance of motor skills have identified a number of issues that contribute to successful performance. For example, variables including anxiety (e.g. Hardy, Beattie, & Woodman, 2007), expertise (e.g. Müller, Abernethy, & Farrow, 2006), and decision making (e.g. Smeeton, Williams, Hodges, & Ward, 2008), together with others such as the use of highly specific psychological skills (e.g. imagery, goal setting, and emotional control; see Hardy, Roberts, Thomas, & Murphy, 2010), have received extensive study within the literature. However, one area that appears to be substantially under-researched concerns basic or low-level perceptual processes that shape the performance of the average human nervous system. One such example is the lateralization of the cerebral hemispheres, and the resultant hemispheric specialization of function (see Springer & Deutch, 1998). Many of these processes have been extensively researched within experimental psychology (e.g. Bowers & Heilman, 1980; Turnbull & Lucas, 2000). However, this phenomenon appears never to have been considered before within sport performance. In the present study, we focused on one of these basic processes, namely lateral biases in visual attention, and examined how these biases may impact on golf putting performance.

It has long been known that visual attention shows a strong right hemispheric dominance (see De Renzi, 1982; Springer & Deutch, 1998). This hemispheric dominance manifests itself most clearly in clinical settings with neurological patients who show symptoms of hemi-spatial neglect, as a result of damage to right parietal areas of the brain (e.g. Halligan & Marshall, 1991). Such visual attention capabilities are readily assessed using simple manual line bisection tasks, where patients are asked to bisect a line at its centre. Patients with hemi-spatial neglect consistently demonstrate catastrophic biases in attention, by bisecting lines to the *right* of centre. Thus, these patients neglect the (left) side of space that is attended to by the damaged (right) side of the brain

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(e.g. Robertson & Marshall, 1993). Neglect of the left side of space by right-hemisphere damaged individuals has also been demonstrated in other domains, where participants are only able to reproduce the right-hand side of drawings (e.g. Driver & Halligan, 1991), or recall more objects on the right-hand side of a scene (e.g. Bisiach & Luzzatti, 1978).

The dominance of the right hemisphere for visual attention is also evident in neurologically normal populations, although the effects are far more modest in size. When such individuals are asked to bisect lines, for example, a clear bias towards the left-hand side of the line is produced, with substantial individual differences in the magnitude of this leftward bias (see Jewell & McCourt, 2000). This phenomenon is known as "pseudoneglect" (e.g. Bowers & Heilman, 1980), where the (leftward) direction of attentional biases is in the *opposite* direction to that found within the neurological population. Although pseudoneglect is readily assessed using simple manual line bisection, other measures have been used to capture the more complex biomechanical elements of lateral bias, making it possible to disentangle specific elements of motor performance. For example, the Bisection Tool (Bisiach, Gemimiani, Berti, & Rusconi, 1990; MacLeod & Turnbull, 1999) requires participants to bisect a line by making explicit lateral movements with a lever that controls a steel bar, and also produces consistent leftward biases in attention.

As well as being evident on experimental tests of line bisection, lateral attentional biases appear to exist in more real-world settings, even though individuals are usually unaware of them. For example, researchers (e.g. Nicholls, Loftus, Orr, & Barre, 2008; Turnbull & McGeorge, 1998) have demonstrated a consistent lateralized bias with regard to collisions, whereby individuals bump into objects (e.g. doors) on the right-hand side more often than the left. Left-sided biases have also been demonstrated in other areas of human functioning, such as the recall of imagined scenes (McGeorge, Beschin, Colnaghi, Rusconi, & Della Sala, 2007) and responses to Likert scale questionnaires (Nicholls, Orr, Okubo, & Loftus, 2006). However, this commonly found leftward bias appears to become a rightward bias when lateral attentional biases are assessed in far space (Longo & Lourenco, 2006, 2007).

Although attentional biases have received interest from researchers within experimental psychology and neuropsychology, to the best of our knowledge no research has considered lateral biases of attention in the context of sporting performance. Nevertheless, one might expect such effects to exist, as attentional biases can be shown on simple line bisection tasks, as well as in other aspects of everyday life (e.g. bumping into objects). One might expect that they should presumably produce effects in sports that require aiming towards a target (e.g. golf putting, archery, shooting). In these sports, a precise knowledge of the position of the target is vital for a successful performance (cf. Karlsen, Smith, & Nilsson, 2008), so that biases in attention may cause the perceived position of the target to be altered. As in all target sports, when locating the hole in golf relative to its surroundings, any bias in attention towards a particular side of space will clearly disrupt accurate aiming, and likely lead to errors in performance.

In the present study, we investigated the effect of attentional biases on the nature of lateral putting errors in golf. Golf was chosen, in part, as it is simpler to examine lateral biases of attention in a dead ball sport (i.e. a sport where the ball is stationary before the task is performed). Moreover, we felt it would be especially interesting to examine the role of attentional biases in golf putting, as golf contains a number of unique factors that are not present in other target sports. First, when putting, a golfer does not stand directly facing the target, so that the retinotopic frame of reference is shifted. In addition, when standing over a putt, all the information regarding the location of the hole is on the left-hand side of the body (for a right-handed golfer), and so increased right hemisphere activation would be expected. Finally, as golfers do not actually look at the hole when putting, it is important to be able to recall the precise location of the hole. Given that leftward biases exist in recall (cf. McGeorge et al., 2007), the effects of attentional biases may be even more evident in putting than other target sports that allow an athlete to view the target while performing.

We hypothesized that lateral biases in attention (i.e. pseudoneglect) would impact on lateral putting errors (such that individuals who bisected lines to the left may show greater leftward putting error than those who bisected lines to the right). Moreover, we expected a greater effect of pseudoneglect on putting performance when pseudoneglect was measured using a test that requires indirect biomechanical movement (i.e. the Bisection Tool) than with manual line bisection, as the explicit lateral movements used by the Bisection Tool align more closely to complex motor skills. Finally, as a supplementary hypothesis, we expected that there would be a larger effect of pseudoneglect on lateral putting errors when pseudoneglect was measured by the left hand, as opposed to the right hand. This is because the use of the left hand during the pseudoneglect tasks requires activation of the right hemisphere and thus would be expected to lead to greater leftward biases. Furthermore, it is of interest that golf teaching manuals (cf.

Leadbetter, 2004) highlight the importance of the left hand (for right-handed golfers) in maintaining a good putting stroke that contains minimal wrist movements. In summary, the importance of the left hand in both putting and pseudoneglect tasks would be expected to contribute to increased right hemisphere activation.

Methods

Participants

Thirty male novice golfers (mean age 23.7 years, $s = 6.0$) participated in the study. To be considered as a novice, participants were required to (a) have not played a full round of golf within the previous 12 months or (b) fewer than five rounds in their entire life. All participants gave their written informed consent to take part in the study. Institutional ethics approval was obtained. Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971). All participants were strongly right handed (mean 83.92, $s = 17.91$).

Measures

Pseudoneglect: Manual Line Bisection. The Manual Line Bisection Task involved bisecting lines with each hand. Using the same methods as MacLeod and Turnbull (1999), 100 black lines (15 cm long) were placed horizontally and centrally on ten sheets of A4 paper, with ten lines per sheet. By using a movable cover, only a single line was visible to each participant at any given time. Participants were required to bisect 50 lines with their left hand, and 50 with their right hand. As in MacLeod and Turnbull, the experimenter determined the magnitude of error (in millimetres). Positive values were assigned to errors deviating to the right of the mid-line, and negative values to errors deviating to the left.

Pseudoneglect: Bisection Tool. The Bisection Tool required participants to move a lever that controlled a steel bar to the mid-point of a line (a small screen of 20×2 cm). The device contained two levers, one that moved the vertical bar in a direction that was *congruent* with the participant's hand, and one that moved the bar in a direction that was *not congruent* with the participant's hand. On the opposing side of the Bisection Tool (out of view of the participants), the experimenter was able to assess the magnitude of error to the nearest millimetre by way of a metal ruler placed on the back of the screen. For simplicity, and given that golf does not involve incongruent movements, in the present study we only assessed attentional biases using congruent movements [interested readers are referred to MacLeod and Turnbull (1999) for more on the effect of movement congruency on pseudoneglect]. Participants completed a total of 48 bisections in two blocks of 24 trials. One block of 24 trials was completed with the left hand, and one block with the right. For each trial, as for the Manual Line Bisection Task, positive values were assigned to errors deviating to the right of the centre of the screen, and negative values assigned to errors deviating to the left.

Putting performance. Participants were required to complete 90 putting trials on an indoor putting green with an "artificial turf" surface that included an incline of 25% between the participant and the hole. Each putt was made from a distance of 2.26 m, to a standard size golf hole (diameter = 108 mm). Standard white golf balls and a standard "blade" putter (Prosimmon, X series) were used by all participants. A digital camera, placed on the ceiling directly above the hole, was used to measure the distance each putt finished from the hole (in millimetres). Putts finishing to the left of the hole were assigned negative values, and putts finishing to the right were assigned positive values.

Procedure

Participants were tested individually, initially completing the putting trials. Upon completion of the 90th trial they were given a 5-min break. Following this break, participants completed the two measures of pseudoneglect (Manual Line Bisection Task and Bisection Tool). The order in which these two measures were administered was counterbalanced across participants. To prevent fatigue, a 5-min break was provided to participants in between the performance of the pseudoneglect measures.

In the Manual Line Bisection Task, participants were seated at a table, and were positioned so that each piece of paper could be placed directly in front of them, with the mid-point of the lines lying in mid-axis to their trunk. They then bisected the 50 lines with each hand. When performing with the Bisection Tool, participants were again seated, and positioned with the Bisection Tool in line with the trunk mid-axis. As with Manual Line Bisection, the Tool was placed directly in front of the participants. To control for the effects of starting side (Jewell & McCourt, 2000), participants were directed to move the steel bar to alternate starting sides before each bisection trial (cf. MacLeod & Turnbull, 1999). The order in which each block of trials was performed was systematically varied across participants.

Results

Data screening revealed one outlier in the sample. The scores for this participant were within normal limits for the Bisection Tool for both right and left hands, but were dramatically different (i.e. *z*-scores equal to or greater than the 99.9th percentile; cf. Tabachnick & Fidell, 2007) from the rest of the sample for Manual Line Bisection (for both hands). The data from this participant were deleted and subsequent analyses performed on 29 participants. Descriptive statistics for the pseudoneglect variables (Manual Line Bisection and Bisection Tool for both left and right hands) and putting performance are provided in Table I. The four pseudoneglect variables displayed a leftward deviation, with putting performance displaying a rightward deviation. Using the methods employed by MacLeod and Turnbull (1999), we used one-sample *t*-tests to examine whether these deviations were significantly different from zero. The *t*-tests revealed that all deviations were significantly different from zero apart from right-handed Manual Line Bisection.

To determine whether putting errors followed lateral biases of attention, participants were grouped as either leftward or rightward bisectors, based on their average deviation from the centre for each pseudoneglect variable (i.e. participants showing an average deviation to the left for a particular variable were classed as leftward bisectors, and those showing a deviation to the right were classed as rightward bisectors). For left-handed Manual Line Bisection, 21 participants were classed as left bisectors and 8 as right bisectors. For right-handed Manual Line Bisection, 18 participants were classed as left bisectors and 11 as right bisectors. For the Bisection Tool with the left hand, 19 participants were classed as left bisectors and 10 as right bisectors. Finally, for the Bisection Tool with the right hand, 21 participants were classified as left bisectors and 8 as right bisectors. To test the specific hypotheses that there would be a greater effect of pseudoneglect on lateral putting errors when pseudoneglect was assessed by the Bisection Tool, and with the left hand, we performed four independent samples *t*-tests with bisection direction (left/right) for each pseudoneglect task as the independent variable and lateral putting error as the dependent variable. Using the familywise rate of controlling for Type I error (see Dar, Serlin, & Omer, 1994), alpha was set as 0.025 for each analysis. No significant differences emerged between the groups (left vs. right bisectors) for putting error for any of the pseudoneglect tasks other than when individuals were classed as left or right bisectors based on performance with the Bisection Tool with the left hand. In this condition, leftward bisectors displayed significantly smaller rightward putting errors ($t_{27} = -2.57$, $P < 0.02$, $d = 0.92$). Figure 1 displays the results of the analyses.

As the results indicated that leftward bisectors (as assessed by the Bisection Tool with the left hand) produced smaller (rightward) putting errors, a follow-up analysis was performed to determine whether this smaller error would translate to more putts being holed. Leftward bisectors (mean = 39.53,

Table I. Mean (*s*) values in millimetres and *t*-values for performance on the pseudoneglect tasks.

Pseudoneglect variable	Average deviation	t_{28}
Manual line bisection – left hand	−1.20 (2.58)	−2.51*
Manual line bisection – right hand	−0.91 (2.73)	−1.80
Bisection tool – left hand	−1.07 (2.08)	−2.77**
Bisection tool – right hand	−0.96 (2.06)	−2.50*
Putting error	18.20 (17.58)	5.58**

*$P < 0.02$, **$P < 0.01$.

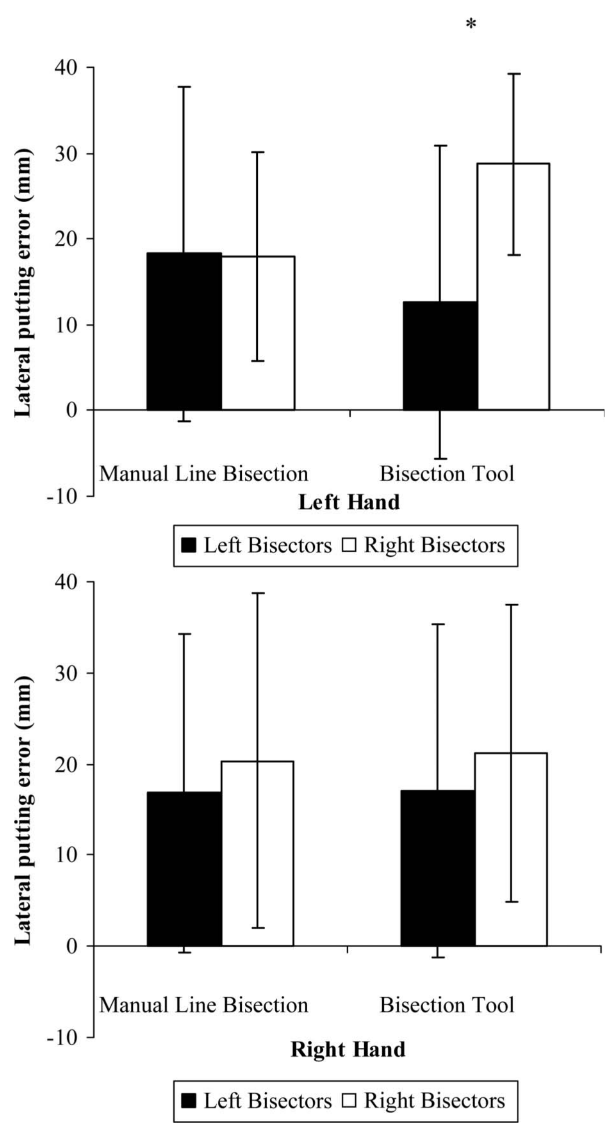

Figure 1. Mean lateral putting error as a function of bisection direction for the left hand (top graph) and right hand (bottom graph). Vertical lines depict one standard deviation. *$P < 0.02$.

$s = 10.40$) holed more putts than rightward bisectors (mean = 34.60, $s = 4.12$), although this difference only approached significance ($t_{25.75} = 1.81$, $P < 0.08$, $d = 0.54$). Despite this result being non-significant at conventional alpha levels (i.e. 0.05), the moderate effect size reported for the analysis (cf. Cohen, 1988) suggests a relatively meaningful effect between these two groups in terms of number of putts holed.

Discussion

In the present study, we examined whether lateral biases in visual attention might impact on putting performance. Attentional biases are a well-researched area of neuropsychology (e.g. Halligan & Marshall, 1991; MacLeod & Turnbull, 1999) but have yet to be considered within the realm of sport. In line with previous research (e.g. Nicholls et al., 2008), the pseudoneglect tasks all revealed leftward deviations (although right-handed manual line bisection was not significantly different from zero). Of more central interest, we obtained a significant rightward bias for lateral putting error and found that attentional biases only affected performance significantly when measured with the Bisection Tool using the left hand. More specifically, in this condition, leftward bisectors demonstrated significantly smaller rightward putting errors (and holed more putts) than rightward bisectors.

While these effects are clear, the underlying mechanisms are more open to interpretation. The fact that particular attentional biases are associated with smaller putting errors may perhaps be explained by the other specializations of the right hemisphere. For example, as well as being involved in visual attention, the right hemisphere plays a significant role in visuo-spatial skills, such as mental rotation (see Turnbull, Carey, & McCarthy, 1997). Thus, an individual with conventional cerebral dominance (i.e. one that bisects lines to the left) would have an enhanced right hemisphere spatial system (for objects in the left visual field), and so might have an improved ability to recall the precise location of the hole when not looking at it. This effect would suggest that left bisectors have a greater capacity to remember and transform spatial reference frames accurately, although this has never been formally investigated, and cannot be readily established using the data from our modest sample. However, this explanation seems unlikely to be able to *completely* explain the present results because lateral putting error was rightward.

Thus, other explanations are likely better suited to explain the data. Given the nature of putting, it is probable that some form of *interaction* between visual attention and the biomechanical elements involved in the putting stroke offers the most convincing explanation of the data. Any account of a behaviour as complex as that of putting must always be multi-faceted. For example, while biases in visual attention may displace the imagined position of the hole in a particular direction, the biomechanical factors that determine the angle and force with which the putter hits the ball naturally also influence the direction of the putt. In addition, the rightward putting bias may be explained by differences in attention between near and far space, given that these types of attentional space are coded differently in the brain (e.g. Halligan & Marshall, 1991), and can lead to contrasting biases in attentional tasks. For example, Longo and Lourenco (2006, 2007) have demonstrated a rightward bias during far space line bisection, when performed with a laser pointer. This perceptual effect has been argued to have an influence over relative hemispheric activation (cf. Longo & Lourenco, 2006), and may well interact with biomechanical factors, producing a putting bias. Although these explanations are encouraging, however, they remain somewhat speculative (especially as there was no comparison of putting performance in near and far space) and warrant further examination.

It also seems appropriate to consider these findings in the context of what is known about the role of action in the dorsal versus ventral visual systems, especially since neglect has repeatedly been shown to influence (ventrally mediated) *perception* rather than (dorsally mediated) *action* systems (e.g. Edwards & Humphreys, 1999; Milner & Goodale, 1995). We note that while putting is clearly a form of action, it lacks the *direct* visuo-motor guidance (as in grasping or kicking movements) that characterizes typical dorsal system activity. Putting is a multi-component process, where hand grasps club, club propels ball, and the ball is influenced by the effects of gravity on a surface (the green) that may contain one or more slopes. Such a multi-stage process is unlikely to use the relatively simple action systems that underpin dorsal stream function. In future, researchers would do well to investigate these issues further, so as to clarify the potential roles of the ventral and dorsal stream during "indirect" multi-component actions such as putting.

Nevertheless, despite these issues of complexity, the results of the present study indicate that attentional biases substantially affect putting performance. In this context, it is remarkable that (to the best of our knowledge) no previous researchers have examined whether attentional biases affect sporting performance. This study consequently opens up a number of potential research questions. First, and most importantly, the possible mediators of this effect (e.g. imagery ability, spatial location coding, reference frame transformation) are poorly understood, and require further examination. In addition, we note that golf is somewhat unique compared with other target sports, in that the task is performed while side-on to the target, and the target is not actually viewed when the task is performed. It would, therefore, be worth considering the effects of attentional biases in situations where the performer is prone to the target (e.g. shooting), and actually views the target while performing (e.g. archery, snooker). Also, it is worth highlighting that our effects were obtained with *novices*, and so an examination of this phenomenon in experts, and a subsequent expert versus novice comparison, would also be interesting. This is particularly pertinent given that the biomechanical aspects of the putting stroke have been shown to play only a limited role in putting performance in experts (Karlsen et al., 2008). Finally, researchers might consider the effects of pseudoneglect on different lengths of putt. Given that the commonly found leftward bias appears to become rightward in far space (cf. Longo & Lourenco, 2006, 2007), it would be informative to examine how pseudoneglect affects putts that are performed in both near and far space.

In summary, in the present study we investigated a previously ignored basic perceptual variable that appears to be involved in a complex biomechanical action. Although these effects appear clear, more testing is required to fully understand precisely how, and under what conditions, pseudoneglect impacts on sport performance. We hope that this preliminary investigation into a relatively unchartered domain will allow motor behaviour researchers to investigate more fully the influence of basic perceptual factors in this important performance domain.

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