

Directional Bias and Environmental Cues in Golf Putting—An Exploratory Study

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The purpose of the current study was to explore the influence of the distance of a wall located behind the hole in performing a putt in golf. Our assumption was that a performance condition where the wall is located a short distance behind the hole would help novices minimize any left/right directional bias. Novice golfers performed a putting task from a distance of two m in front of the hole in two learning settings. In the Far Wall Condition, a wall was located 4 m behind the hole, and in the Close Wall Condition the wall was located 90 cm behind the hole. The putt was performed under both quiet and distracted conditions. Results showed that overall accuracy was greater in the Close Wall Condition than in the Far Wall Condition. In addition, different patterns of left/right directional bias in the two performance conditions were observed. However, the hitting deviations were more balanced in the Close Wall Condition. It is recommended that coaches consider the use of environmental cues that have the potential to improve accuracy in golf putting.

Keywords: golf, motor learning, putting, varied conditions

Putting is one of the most commonly-used strokes in golf, both in practice and competition settings. Novice and advanced golfers alike allocate a considerable amount of time in their practice sessions attempting to improve the accuracy of the putting task to achieve a high level of proficiency (Stirling, 1994; Wesson, 2009). Accuracy of putting was examined in a number of studies (see, for example, Roberts & Turnbull, 2010; Van Lier, Van der Kamp, & Savelsbergh, 2011; Van Lier, Van der Kamp, Van der Zanden, & Savelsbergh, 2011; Ziv & Lidor, 2015), where two dimensions of accuracy were typically measured: (a) the overall accuracy of putting—the distance the ball landed from the hole for each shot, without regard to direction, and (b) the consistency of the shot—the standard deviation of the cluster of hits. According to Schmidt and Lee (2011), these two dimensions of accuracy complement each other and provide necessary knowledge concerning the results of the actions performed. Information on how close the ball is to the target and how

consistent the golfer is in his or her attempts to putt can assist coaches/golfers in analyzing the putting act, and therefore in making relevant adjustments/changes to improve performance.

Other dimensions of accuracy that may add relevant information to the assessment of the golfer's putting ability are missed putts that are short or long of the hole, and the left/right directional bias—the direction the ball lands relative to the hole. For example, the difference between the number of missed putts landing to the left and to the right of the hole in a given set of strokes can be determined, and then compared with the difference between the number of missed putts landing to the left and to the right of the hole in another set of strokes that was performed under different environmental or instructional conditions. The analysis of directional bias can assist coaches in obtaining more information on the golfer's accuracy, and consequently in developing task-enhancement instructional units that can help golfers minimize this bias and become more consistent in their strokes.

Some coaches are aware of the concept of left/right directional bias when instructing golfers on how to improve their putting accuracy (see Langer, 1987; Stirling, 1994). Coaches often use environmental cues and instructional aids that have the potential to assist golfers in minimizing deviations to the left or to the right of the hole, for example by placing golf clubs on the grass a number of centimeters to the left/right of the hole or at the back of the hole before the putting drills. It is possible that by placing the clubs horizontally and/or vertically on the ground in relation to the hole, the coach can help golfers narrow their attention and focus effectively on an external cue (e.g., on the hole). In this way, coaches can reduce the number of irrelevant cues that may attract the golfer's attention, and hence enable him or her to putt the ball as close to the hole as possible.

The use of environmental cues aimed at improving accuracy in golf putting should be evidence-based. To strengthen the rationale for the selection of task-enhancement environmental cues in learning how to putt in golf, data should be collected on their effectiveness in increasing proficiency. Unfortunately, data on the use of environmental cues in the learning processes in golf are limited. Therefore, in the current exploratory study our purpose was to examine the effects of the distance of a wall (i.e., an environmental cue) located behind a golf hole on putting performance in novice learners. Our assumption was that a performance setting where the wall is located a short distance behind the hole would help novice golfers effectively focus on the hole. As a consequence, this would decrease the deviations to the left or to the right of the hole (i.e., the left/right directional bias) as compared with a performance setting where the wall is located far from the hole.

In a recent laboratory study, Ziv and Lidor (2015) examined the effectiveness of internal (focusing on the swinging motion of the arms) and external (focusing on the pendulum motion of the club head) focus of attention instructions on the performance of a golf-putting task under nondistracted and distracted (noisy) conditions. In addition, the relationship between attentional focus instructions and gaze behavior under these two conditions was studied. Three main findings emerged from this study: (a) under distracted conditions, higher performance accuracy was observed in both the internal and external attentional focus participants than in the participants who were not provided with attentional instructions; (b) under nondistracted conditions, quiet eye durations were longer in the external participants than in the internal participants or in the participants who were not provided

with attentional instructions; and (c) the overall accuracy of putting performances was improved in a setting where novice golfers were asked to putt into a golf hole located 90 cm in front of a wall compared with a setting where the wall was located 4 m from the hole.

One finding that emerged from Ziv and Lidor's (2015) study, namely that accuracy of putting performances can be improved by the distance of a wall located behind the hole or target (i.e., a circle drawn on an artificial grass mat), was not expanded upon by the researchers in the study, due to the fact that the main purpose was to explore the relationships between focusing attention instructions—internal and external, and gaze behavior. Explanations of why a wall that is located at a certain distance from the target can help novice golfers to aim better were not provided. However, this finding is of particular interest for coaches/instructors who teach novice golfers and aim at minimizing the golfers' hitting deviations from the hole. While research on the use of instructional aids and environmental cues in teaching novice golfers how to putt is scarce, walls located in closed spaces (e.g., gyms) where novice golfers can practice their strokes have the potential to help them aim effectively at the target.

In closed self-paced motor tasks, such as putting in golf, the performance takes place in a stable and predictable environment (Lidor, 2007). Attention should be narrowed and directed to a target (e.g., the hole in golf). The ability to be focused before and during a specific action (e.g., putting in golf) is crucial in determining proficiency. Research has shown that external focusing attention on one relevant environmental cue is more effective than internal focusing attention (i.e., focusing on the body and feeling of the performed acts), when closed self-paced motor tasks are performed (e.g., Wulf, 2013; Wulf & Su, 2007). While performing a putt in golf (a closed self-paced task), it may be beneficial for the novice golfer to perform the task in a performance condition where the area appears smaller, and therefore he or she can be more effective at focusing attention. That is to say, manipulating the space in the performance setting where the putt is practiced (e.g., the distance of a wall behind the hole) may assist the golfer in focusing before and during the act of putting.

In the current study our main aim was to further explore the contribution of a wall located close behind the hole in facilitating the learners' accuracy, namely reducing left/right directional bias. We also aimed at examining how challenging conditions can influence the left/right directional bias dimension, by having the participants perform the putting task under distracted (noisy) conditions. The participants in our study were naive to the performed golfing task, and did not have any experience in playing golf before their participation in the current exploratory study. Since we did not want to expose the novice golfers to dramatic changes in their performance environment, we selected noisy conditions; it was our objective to examine their putting accuracy in a condition where they would be lightly distracted. In essence, the inclusion of noisy conditions in our study created a simple transfer condition, where the novice participants were challenged to maintain their accuracy of performance (see Schmidt & Lee, 2014). We assumed that under these distracted conditions the left/right directional bias would be more apparent than under nondistracted conditions, due to the potential negative influence of noise on performance (e.g., accentuating perception of the potential cues that cause the bias).

Method

Participants

Twenty-three right-handed male students enrolled in physical education (PE) classes (age: $M = 26.3$ years, $SD = 4.0$, range = 21–37 years) at a PE teacher’s college in Israel participated in the study. The students were in their sophomore or junior year at the college. None of the participants had any prior experience in playing golf. The game of golf is not one of the most popular sports in Israel, and only a small number of people play golf on a regular basis. The participants were recruited through both verbal advertising in classes and printed advertisements that were placed on bulletin boards around the campus. The study was approved by the Ethics Committee of the Zinman College of Physical Education and Sport Sciences. All participants signed an informed consent form before participation.

The Putting Task

A putting task in golf was performed at the Motor Behavior Laboratory by the participants in two learning settings, where the distance of a wall located behind the hole was manipulated. The wall was over 2.5 m tall, and was painted white. The manipulation of the distance between the back wall and the hole in the learning environment was also used by Ziv and Lidor (2015). Figure 1 presents a participant in the current study standing at a ready position and performing the putting task in the two learning settings.

Far Wall Condition. The golf putt was performed from a distance of two m on a $1\text{m} \times 4\text{m}$ piece of artificial grass. The golf club used by all participants was a putter (34” in length, zinc 2-way putter), and the ball was a regulation golf ball (diameter = 42.67 mm, mass = 45.93 g). A circle with a diameter of 108 mm, representing a regulation golf hole, was painted on the grass, and the distance between the hole and the back wall was four meters.

Close Wall Condition. The putting task was performed the same as in the Far Wall Condition. However, before starting the task the participant was turned

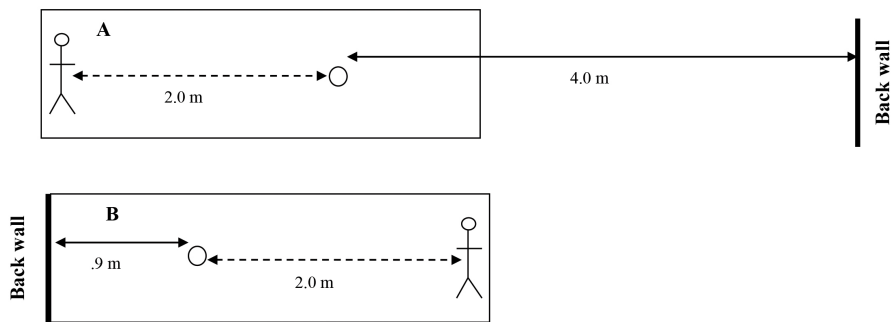


Figure 1 — A participant standing at a ready position and performing the task in the Far Wall Condition (A) and the Close Wall Condition (B). Figure is not drawn to scale.

around 180°, so that the wall in front of him (now the back wall) was only 90 cm behind the hole. This change allowed us to examine whether the presence of a close obstacle behind the hole affected performance.

Procedure

The study was comprised of two testing days. Before testing, participants practiced the putting task for two days. Two to four days elapsed between the two testing days.

Practice. Since the putting task was novel to the participants, it was our aim to provide them with the opportunity to practice before data collection. We assumed that it would be more beneficial for them to acquire the golf task under quiet conditions, and only then to perform under more challenging conditions.

Upon arrival at the Motor Behavior Laboratory, the participants were provided with a general description of the experiment. They were then given technical instructions on how to putt a golf ball, including the correct posture, the correct way to hold the golf club, and the correct way to swing the arms. The total length of instructional provision was about six minutes.

After the instructions were given, each participant practiced the golf-putting task for two days, with six blocks of 10 trials on each day. Participants were provided with a rest interval of two minutes between blocks. The number of blocks and trials was selected based on pilot data which revealed that a plateau in performance is reached after the sixth block. In total, each participant completed 120 trials of the golf-putting task in the 2-day practice sessions, 60 trials on each day. The practice conditions were the same as the ones presented to the participants in the Far Wall Condition, namely that the distance between the hole and the back wall was four meters. In essence, the Far Wall Condition—the first performance condition presented to the participants in our exploratory study—was an extension of the practice conditions. In addition, we did not measure the accuracy of the putting task during practice, since the aim was to enable the participants to practice the novice skill in comfortable and relaxed settings.

Testing Day 1—Far Wall Condition and Close Wall Condition. In the Far Wall Condition, participants performed the golf-putting task for two blocks of six trials, with a 2-minute rest between each block. The identical procedure was applied in the Close Wall Condition. A total of 24 putts were performed on Testing Day 1.

Testing Day 2—Far Wall Condition and Close Wall Condition Under Quiet and Distracted Conditions. The Far Wall Condition and the Close Wall Condition were repeated on Testing Day 2. However, on Testing Day 2, 12 participants performed these tasks under quiet conditions and 11 participants performed the task under audio-distracting conditions. Participants were randomly assigned to the quiet or the audio-distracting conditions. Under the audio-distracting conditions, participants performed the tasks while noisy sounds (85dB) were played on a portable CD player. Noises included drums and other percussion instruments, the clattering of moving railroad wheels, and hammer blows in a metalworking shop. The duration of the noises was approximately two seconds each time, and the noises were played at random intervals while the participants performed the putting tasks. The noise appeared either before, during, or after putting the ball, and therefore distracted the participants while they were (a) planning the putting

execution and (b) executing the putt. A volume of 85dB was selected, as this has been determined to be a safe level for short periods of time (U.S. Department of Labor—Occupational Safety and Health Administration, 2002).

Dependent Variables

Four dependent variables were measured: (a) absolute error (AE)—a measure of overall accuracy in performance: the distance the ball landed from the edge of the 108 mm painted circle for each shot, without regard to direction; (b) left/right directional bias—the direction the ball landed relative to the target; (c) missed putts landing short or long of the target; and (d) bull's-eyes—landing on the golf target.

Statistical Analyses

For Testing Day 1, AE was analyzed using a paired *t* test. A two-way ANOVA with repeated measures was used on the data of missed putts to determine whether the number of missed putts landing to the left of the target or to the right of the target differed between the Far Wall Condition and the Close Wall Condition. A two-way ANOVA with repeated measures was also performed on the data of missed putts landing short or long of the target. For the bull's-eyes' data, only descriptive statistics are presented, due to the small number of cases.

For Testing Day 2, a two-way ANOVA (Noise x Condition) with repeated measures on the latter factor was used to reveal whether AE, the difference between the number of missed putts landing to the left of the target or to the right of the target, and the difference between the number of missed putts landing short or long of the target differed between noisy and quiet conditions and between the Far Wall Condition and Close Wall Condition. Fisher Least Significant Difference (LSD) was used as a post hoc procedure, where appropriate. Effect sizes (η^2) were reported when needed. Alpha was set at .05 for all statistical tests.

Results

Results are presented separately for Testing Day 1 (Far Wall Condition and Close Wall Condition) and Testing Day 2 (Far Wall Condition and Close Wall Condition under quiet and under distracted conditions). In addition, findings are presented separately for each dependent variable.

Testing Day 1

AE. The *t* test revealed that AE was lower (23.26 ± 7.65 cm) in the Close Wall Condition compared with the Far Wall Condition (30.06 ± 8.76 cm), $t(22) = 4.12$, $p < .001$, $ES = .78$.

Left/Right Directional Bias. A two-way ANOVA with repeated measures revealed a main effect for missed putt side, $F(1, 22) = 23.12$, $p < .01$, $\eta^2 = .51$. More putts were missed to the right side compared with the left side (6.39 ± 3.68 vs. 1.83 ± 5.53 for the Far Wall Condition and the Close Wall Condition, respectively). More importantly, a significant Condition x Missed Putt Side interaction was found, $F(1, 22) = 22.74$, $p < .01$, $\eta^2 = .51$. Analysis of this interaction revealed

that in the Far Wall Condition more putts were missed to the right side (8.96 ± 2.01) compared with the left side (2.57 ± 1.73) of the target. However, the difference between the missed putts landing to the right of the target and to the left of the target was smaller in the Close Wall Condition (6.70 ± 2.79 to the right and 4.87 ± 2.79 to the left). Figure 2 describes the number of missed putts in the Far Wall Condition and Close Wall Condition on Testing Day 1. However, the differences that were found between the Far Wall Condition and the Close Wall Condition were not significant, $F(1, 22) = .06, p = .80, \eta^2 = .003$.

Missed Putts Landing Short or Long of the Target. Neither main effects nor an interaction was found: $F(1, 21) = .06, p = .80, \eta^2 = .003$ for condition, $F(1, 21) = .03, p = .85, \eta^2 = .002$ for location (near/far), and $F(1, 21) = 1.73, p = .20, \eta^2 = .073$ for the interaction.

Bull's-Eyes. Out of 552 putts performed in the Far Wall Condition and Close Wall Condition, only 11 and 10 putts landed exactly on target, respectively (2.0% and 1.8%, respectively).

Testing Day 2

AE. The two-way ANOVA revealed a main effect for noise, $F(1, 21) = 5.91, p = .024, \eta^2 = .22$ and a main effect for condition, $F(1, 21) = 11.33, p = .003, \eta^2 = .35$. AE was higher (e.g., lower overall ability of accuracy) under noisy conditions

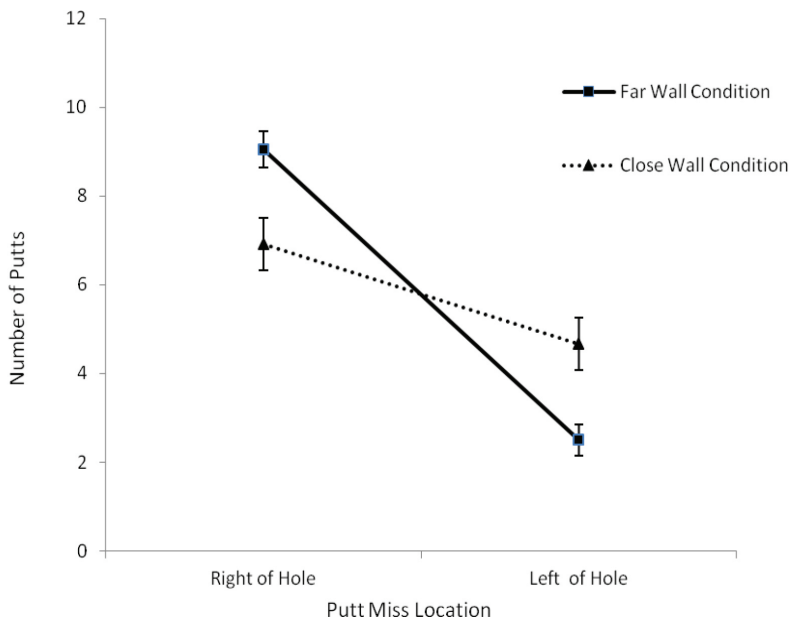


Figure 2 — The number of missed putts in the Far Wall Condition and the Close Wall Condition on Testing Day 1. Error bars represent the standard error of measurement.

(30.46 ± 7.72 cm) compared with quiet conditions (23.64 ± 5.68 cm; higher overall ability of accuracy). In addition, AE was higher in the Far Wall Condition (30.18 ± 8.16 cm) compared with the Close Wall Condition (23.62 ± 9.30 cm). No significant interaction was found, $F(1, 21) = .099, p = .756, \eta^2 = .005$.

Left/Right Directional Bias. The two-way ANOVA revealed a main effect for condition, $F(1, 21) = 35.89, p < .001, \eta^2 = .63$. The difference between the number of missed putts landing to the left of the hole and to the right of the hole in the Far Wall Condition was 7.13 ± 4.60, and the difference between the number of missed putts landing to the left of the hole and to the right of the hole in the Close Wall Condition was 2.61 ± 4.66. More specifically, in the Far Wall Condition more putts were missed to the right side of the hole (9.43 ± 2.27) compared with the left side of the hole (2.30 ± 2.34), while in the Close Wall Condition this difference was reduced: 7.04 ± 2.29 misses to the right and 4.43 ± 2.43 misses to the left. Neither the main effect for noise [$F(1, 21) = 1.82, p = .19, \eta^2 = .08$] nor the interaction between the noise and the learning setting [$F(1, 21) = 2.87, p = .44, \eta^2 = .10$] was found to be significant. That is to say, distracted conditions did not significantly influence left/right directional bias. Figure 3 describes the number of missed putts in the Far Wall Condition and Close Wall Condition on Testing Day 2.

Missed Putts Landing Short or Long of the Target. Neither main effects nor an interaction was revealed for the difference between putts landing short or long of the target: $F(1, 22) = .86, p = .360, \eta^2 = .04$ for noisy/quiet conditions, $F(1, 22) = .28, p = .60, \eta^2 = .01$ for the Far Wall Condition/Close Wall Condition, and $F(1, 22) = .39, p = .54, \eta^2 = .02$ for the interaction.

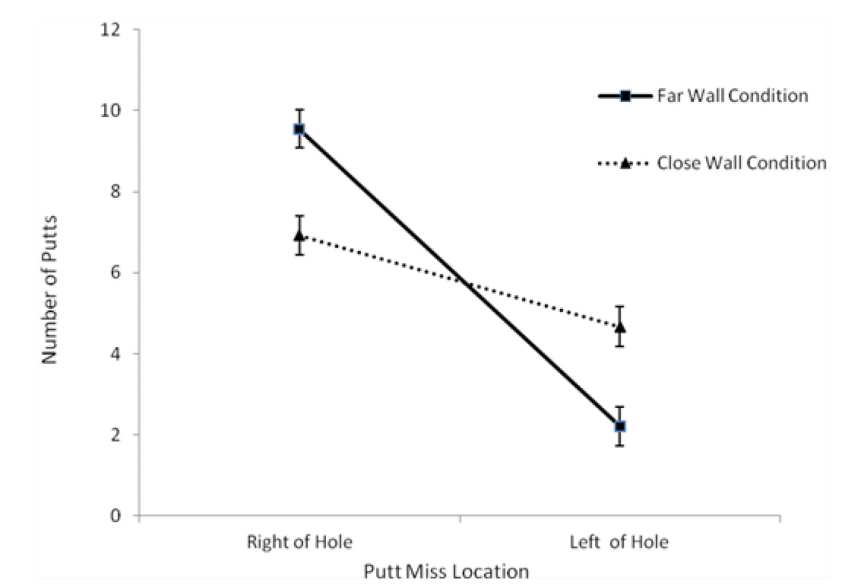


Figure 3 — The number of missed putts in the Far Wall Condition and the Close Wall Condition on Testing Day 2. Error bars represent the standard error of measurement.

Bull's-Eyes. In the Far Wall Condition, under quiet conditions, six out of 144 putts landed exactly on the target (4.2%), and under noisy conditions, none out of the 132 putts landed exactly on the target. In the Close Wall Condition, under quiet conditions, eight out of 144 putts landed exactly on the target (6.1%), and under noisy conditions, four out of 132 putts landed exactly on the target (3.0%).

Discussion

The main findings that emerged from the current study were that the overall accuracy of the putting performances was better in the Close Wall Condition than in the Far Wall Condition, and that different patterns of left/right directional bias were observed during the two days of testing. On Testing Day 1, in the Far Wall Condition most missed putts landed to the right side of the hole. However, a similar number of missed putts landed to the left and to the right sides of the hole in the Close Wall Condition. On Testing Day 2, most missed putts landed to the right side of the hole under both quiet and noisy conditions in the Far Wall Condition. This bias was also observed in the Close Wall Condition, however the gap between the balls landing to the right side of the hole and those landing to the left side of the hole was smaller. In fact, during the Close Wall Condition putts started to drift more often to the left side of the hole. This finding suggests that the learning of a self-paced motor task is not based solely on the intrinsic coordinates, but also on the extrinsic coordinates and environmental cues.

It is possible that in the Close Wall Condition the experimental area may have appeared smaller to the participants, due to the presence of the wall only 90 cm behind the target. This scene was different in the Far Wall Condition, where the hole was located at a distance of four meters from the wall (see Figure 1). This environmental cue—the smaller space in the back of the hole (the distance from the wall)—may have led to the differences in the overall accuracy and missed putt direction.

One possible explanation for the directional bias lies with the perception of the direction between the ball and the target. For example, when putters' line of sight is to the left of the ball, there is a tendency to miss to the right, and when the line of sight is to the right of the ball, there is a tendency to miss to the left. In contrast, when the line of sight is directly perpendicular to the ball, the directional bias disappears (Van Lier, Van der Kamp, & Savelsbergh, 2011). While the line of sight of our participants was not measured, it is likely that their eyes were not focused directly above the golf ball. Therefore, since they were all right-handed, we expected that most putts would miss to the right.

The fact that the directional bias was reduced can be explained in two ways. First, it is possible that with practice, the participants learned to overcome this bias. However, they only performed an extra 12 putts when facing the wall. The second explanation lies with the distance from the hole of the wall itself. While this is only a speculation, the visual directional illusion could be more apparent when there is a larger space behind a target. In contrast, the illusion may be reduced when there are environmental cues that limit the space around a target. This explanation should be further examined in additional research.

Another theoretical framework that can be used to explain the findings of the left and right directional bias found in the current study deals with two visual systems—the ventral visual system and the dorsal visual system (see Van Der Kamp, Rivas, Van Doorn, & Savelsbergh, 2008). The ventral visual system is essential for perception; it deals with explicit awareness and uses information from extrinsic coordinates (i.e., from the environment) that specify, for example, the location, size, and motion of an object in relation to other objects. In contrast, the dorsal visual system controls movement and requires specific information on the location, motion, and size of an object relative to the performer, and therefore this system deals with information relative to intrinsic coordinates. Importantly, Van der Kamp et al. (2008) suggested that novices' performance relies strongly on information from the ventral visual system until the dorsal system takes over, when movements become automatized.

The dissociation between these two systems was shown in a golf-putting experiment (Johnston, Benton, & Nishida, 2003) where skilled golfers were asked to state whether a pointer placed at the ball's location was pointing at the target. Perceptual biases occurred when the golfers stood to the left or to the right of the center. However, this perceptual bias did not result in bias in the actual putting. Therefore, it appears that in these experts the dorsal visual system, which relies on egocentric information, was not deceived by the visual illusion when they stood to the side of the aiming line. However, as indicated previously, novices are prone to be affected by environmental information, as observed in the current study. Therefore, it is possible that the new environmental information used by the participants in the Close Wall Condition affected performance, as this information was processed by the ventral system (i.e., using perceptual information) and complemented the information received by the dorsal system (relative to intrinsic coordinates).

In the current study, we created challenging conditions for the second day of testing to examine any potential negative changes in the left/right directional bias. More specifically, it was assumed that the left/right directional bias would increase under noisy conditions. The data obtained in our study did not support this assumption: the distracted (noisy) conditions were not found to affect the left/right directional bias. It should be noted that the distraction (i.e., noise) presented to some of the learners in Testing Day 2 did not mimic actual distractions that golfers might face in practice/competition (e.g., weather conditions, crowd noise). In addition, the participants in our study were randomly assigned to the noise/no-noise conditions. In this condition, only 12 putts (2 blocks $\times$ 6 trials) were performed by the participants, and therefore the amount of practice was limited.

In addition, in our study the order of the far/near wall conditions was set for each testing day: the participants performed first under the Far Wall Condition and only then performed under the Near Wall Condition. The reason for the selection of this order was that we aimed at providing the participants with the performance conditions that were similar to the ones that they were exposed to during the practice condition. We followed this procedure on both days of testing. However, instead of using a fixed order for all the participants, a counterbalance design could have been selected as well. We suggest that future studies use counterbalance designs, and in addition implement more realistic auditory and/or visual distractions. While introducing auditory/visual distractions, a more

tightly controlled approach should be adopted, namely that the minimum and maximum limits of the noise presentation should be reported to effectively control the presentation of the distracted variable.

Based on the data obtained in our exploratory study, it was observed that the hitting deviations—either to the left or to the right of the hole—were more balanced in the Close Wall Condition than in the Far Wall Condition, in both days of testing. Having the close distance of the wall from the hole may have helped the novice golfers to be more balanced in their deviations. However, it should be noted that in the current study we did not include a putting condition where there was no wall within view of the participants. As indicated before, the participants in the current study were naive to the performed putting task, and did not have any experience playing golf before their participation in our study. Therefore, we preferred to provide them with optimal sterile conditions for practicing the putt. This is the reason why we did not include a putting condition where there was no wall within view of the participants (e.g., a golf course). It can be speculated that the practice sessions had already caused a bias since a wall was present, and hence the absence of a condition where there was no wall within view of the participants might be a limitation of the current study.

Two additional limitations of the current study should be mentioned. First, the participants in our study completed a relatively small number of practice trials (120). It is suggested that in future studies on putts in golf, a greater number of practice trials should be provided to the participants (e.g., 150, 180) to enable them to further benefit from the practice phase. Second, performance was not measured during the practice trials in our study, and thus it was not possible to assess the learning trajectory and skill level of the beginning golfers. Therefore, caution should be taken by practitioners before applying the findings of the current study to golfers who are not at the stage of early learning.

Taking into account the above-mentioned limitations, the findings that emerged from the current study suggest that when teaching individuals who are in the very first stage of learning the game of golf how to putt a golf ball, golf coaches may consider the use of environmental cues that have the potential to enhance the accuracy of strokes, such as in the putt. To examine the contribution of environmental cues in facilitating accuracy in putting, as well as to assist more experienced golfers in increasing their consistency (e.g., minimizing left/right directional bias), additional studies should be conducted in which different cues are used (e.g., cones located around the hole to limit the area of hitting, clubs placed on the grass to assist in directing the ball) and a number of accuracy dimensions are measured (e.g., the overall accuracy of performance, the consistency of performance). In addition, verbal information on how learners perceive the use of such cues in the learning process should be collected as well.

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