



## Accuracy and Gaze Behavior of a Closed, Self-Paced Task Performed Under Varied Conditions

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### Abstract

Closed, self-paced tasks are typically performed in a stable environment, but some features of the environment may vary (e.g., quiet/noisy conditions) or may negatively influence the outcome of performance. Optimal gaze behavior, and specifically long quiet eye (QE) durations, has been found to be associated with improved performance of closed, self-paced tasks. The purpose of the current study was to examine the relationship between QE and accuracy of a golf-putting task under both quiet and distracted conditions in 24 male physical education students. Accuracy of performance and gaze behavior were measured in both conditions. Data analyses revealed that the presence of noise led to reduced quiet eye duration and accuracy, and that golf-putting performances improved in a transfer task compared to both acquisition and retention tasks. Future studies should examine whether maintaining QE durations, or training for longer QE durations, can prevent deterioration in performance under distracted conditions.

### Keywords

Gaze behavior; Learning; Quiet eye; Athletic performance; Sports; Golf; Motor learning

### Introduction

Over the past two decades empirical data on the usefulness of different gaze behaviors during the performance of closed, self-paced tasks have been accumulated [1]. Gaze behavior refers to the location and timing of the fixation of the eyes. Closed, self-paced motor tasks are those taking place in a relatively stable and predictable environment where there is adequate time to prepare for their execution [2,3]. In these tasks, performers can plan their actions in advance and activate a physical/psychological routine [4]. Examples of closed, self-paced motor tasks are free-throw shooting in basketball, dart throwing, and golf putting. For golfers who are attempting to perform a putt, the environmental settings are relatively predictable and stable – the ball is placed on the ground and does not move, the hole does not change its location, and the players swing when they feel ready. However, a number of external features that are related to the settings where closed, self-paced tasks are performed may vary, among them noise conditions or visual distractions.

Specific gaze behavior was found to be associated with attaining a high level of proficiency when performing closed, self-paced tasks. One specific attribute of gaze behavior is the quiet eye (QE). QE is defined as the final fixation on a specific location or object in a visuomotor workspace within 3° of a visual angle for a minimum of 100 milliseconds (msec), with an onset that begins before the final movement of the performed task and an offset that occurs when the fixation deviates from this specific location by more than 3° [1]. It was found in a series of studies in which gaze behavior was measured that longer QE durations were associated with improved performances of closed, self-paced motor tasks [5-9].

One example of a closed, self-paced task in which QE was found to be associated with improved performance is golf putting. Vickers [10] found that QE durations of approximately 1,700 msec were related to high-skilled golfers during putting, and QE durations of approximately 900 msec were related to low-skilled golfers. In another study [11], QE durations were longer in holed putts (1693.50 ms) compared to missed putts (1231.03 ms). These studies were performed under non-distracting conditions.

A number of studies did examine the relationships between QE and achievement under stressful conditions [8,12-17]. In general, these studies showed that ineffective gaze behavior (i.e., gaze behavior with too many fixations of short duration and with short QE durations) is related to a reduced ability to perform and that longer QE durations are associated with a high level of achievement. However, we have not found any studies that examine the relationship between gaze behavior and distractions. In real-life sport settings, performers may find themselves executing a closed, self-paced motor task under noisy conditions that have the potential to hinder the accuracy of their performance. Although performers are provided with time intervals to prepare themselves for the execution of the closed, self-paced task – for example while preparing themselves to perform a free-throw shot in basketball [2], the presence of noisy (distracted) conditions may negatively influence their ability to focus on the appropriate environmental cues, and in turn impede their ability to achieve a high level of proficiency in the given task. That is to say, under noisy conditions QE durations may be altered (e.g., shorter durations than the QE durations under quiet conditions), and subsequently a deterioration in performance may follow.

In one study on the relationships between QE and achievement under stressful conditions [12], a computer-simulated archery task was performed under both no-stress and stressful conditions. In the stressful condition, the scores of the archery task were counted towards a group competition with prize money, and the individual scores were circulated to all participants. It was found that QE duration was significantly shorter under these stressful conditions than under conditions with no stress (50.4% and 61.9% of alignment with the target phase, respectively). Similarly, QE of expert golfers was significantly shorter prior to the last missed putt compared to the successful putts in a "shootout" putting task that required participants to hole as many putts as they could from five feet without missing [14].

In another study [8], elite biathlon athletes performed biathlon rifle shooting under both low pressure (i.e., the athletes were told that

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the experiment was conducted simply to measure their gaze fixations) and high pressure (i.e., the athletes were informed that the Olympic team coach was present, and they were told that their results would influence their selection for the Olympic team) conditions. The results of this study demonstrated that those athletes who maintained QE in biathlon shooting under normal conditions were also able to maintain a high level of performance under elevated pressure conditions. Hence, it was concluded that an adequate QE duration appeared to help the athletes deal effectively with the stressful condition they were facing (i.e., selection to the Olympic team) while performing the shooting task.

One possible explanation as to why adequate QE duration assists athletes in performing better under pressure is that it allows for better information processing. Indeed, at least two studies show that the reason QE is associated with a high level of proficiency lies with using the information processing approach [9,18]: Adequate QE durations can help performers in facilitating three main aspects of the information processing process – stimulus identification, response selection, and response programming. A second possible explanation for the need to retain adequate QE durations is that longer QE durations can assist performers in improving their attentional control [19]. Attentional control can be divided into goal-directed attention (which is influenced by previous knowledge and experience) and stimulus-driven attention (which is influenced by salient sensory stimuli) [20]. The attentional control theory suggests that anxiety can disturb the balance between goal-directed and stimulus-driven attention by shifting attention from the former to the latter [21]. Such a disturbance can negatively affect performance; longer QE durations can help performers alleviate this disturbance and therefore maintain the quality of the performed act.

Finally, it was found that QE can be trained in athletes in order to improve their accuracy under anxiety. In one study of golf putting under high cognitive anxiety [13], a QE-trained group of novices performed more accurately and had more effective gaze control than a technically-trained group. In this study, QE was used as an independent variable (i.e., an imposed technique), while in most other studies it was used as a dependent variable.

To further study the relationships between gaze behavior – particularly QE – and achievement in closed, self-paced motor tasks performed in varied conditions, our purpose in this investigation was to examine the performance of a laboratory golf-putting task under (a) quiet conditions (performing the putt in quiet and sterile conditions; acquisition task), (b) transfer conditions (performing the putt after turning around 180° and at a different distance from a back wall), and (c) distracted conditions (performing the task under unfamiliar noisy conditions).

For the transfer condition, the distance between the beginning learner and the wall located behind the hole was manipulated. In closed, self-paced motor tasks, such as putting in golf, the performance takes place in a stable and predictable environment [2]. Attention should be narrowed and directed to a target (e.g., the hole in golf). The ability to be focused prior to and during a specific action (e.g., putting in golf) is crucial in determining proficiency [22-29]. 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 prior to and during the act of putting.

We aimed at examining the performance of the golfing task not only under quiet conditions (i.e., sterile conditions), but also under distracted conditions. Since the participants in our study were naive to the performed golfing task, and did not have any experience in playing golf prior to their participation in the current exploratory study, noisy conditions were selected. We did not want to expose the beginning golfers to dramatic changes in their learning environment; however, it was our objective to examine their putting accuracy in a condition where they would be lightly distracted. We assumed that even under these slightly noisy conditions, the novice participants would be anxious, and therefore would shift their attention to irrelevant environmental cues (i.e., the noise) instead of focusing solely on the hole (the main external cue) [17-21]).

We selected a two-phase design for the current study – Phase 1 and Phase 2. It was our assumption that it would be more beneficial for the novice participants to acquire the golfing task under quiet conditions (Phase 1: acquisition, retention, transfer), and only then to perform under more challenged conditions – the distracted trials (Phase 2). In Phase 2, we wanted to create a control condition (i.e., a quiet condition) for the distracted condition, and therefore the participants performed the same task under quiet conditions as well. This two-phase research design was also used in a previous study [22].

Three assumptions were made in the current study: (a) longer QE durations will be associated with improved performance (i.e., accuracy and consistency of performance) under all conditions – quiet, transfer, and distracted; (b) performance will deteriorate under distracted conditions due to the potential negative influence of noise on performance (e.g., accentuating perception of the potential cues that cause the bias); and (c) deterioration in performance will be accompanied by reduced QE duration.

## Methods

### Participants

Twenty-four male physical education students from the same college (age:  $M=26.1$  years,  $SD=4.0$ , range=21-37 years) participated in this study. None of the participants had any prior experience in playing golf. For the purpose of this study, we deliberately selected participants who had no prior experience in this sport in order to examine the accuracy and gaze behavior in a novel task – a golfing task. The game of golf is not among the most popular sports in Israel, and only a small number of people play golf on a regular basis. The participants were recruited to participate in the study through both verbal advertising in classes and written notices that were placed on bulletin boards around the campus. The study was approved by the Ethics Committee of the Academic College at Wingate. All participants signed an informed consent form prior to participation.

### The golf tasks

Two golf tasks were performed by the participants in this study: an acquisition task and a transfer task. Figure 1 presents a participant standing at the ready position and performing the acquisition task (A) and the transfer task (B). Both the acquisition task and the transfer task were identical to those used by Ziv and Lidor [22] in an exploratory study examining the relationships between internal and external attentional instructions and gaze behavior in performances of putting in golf.

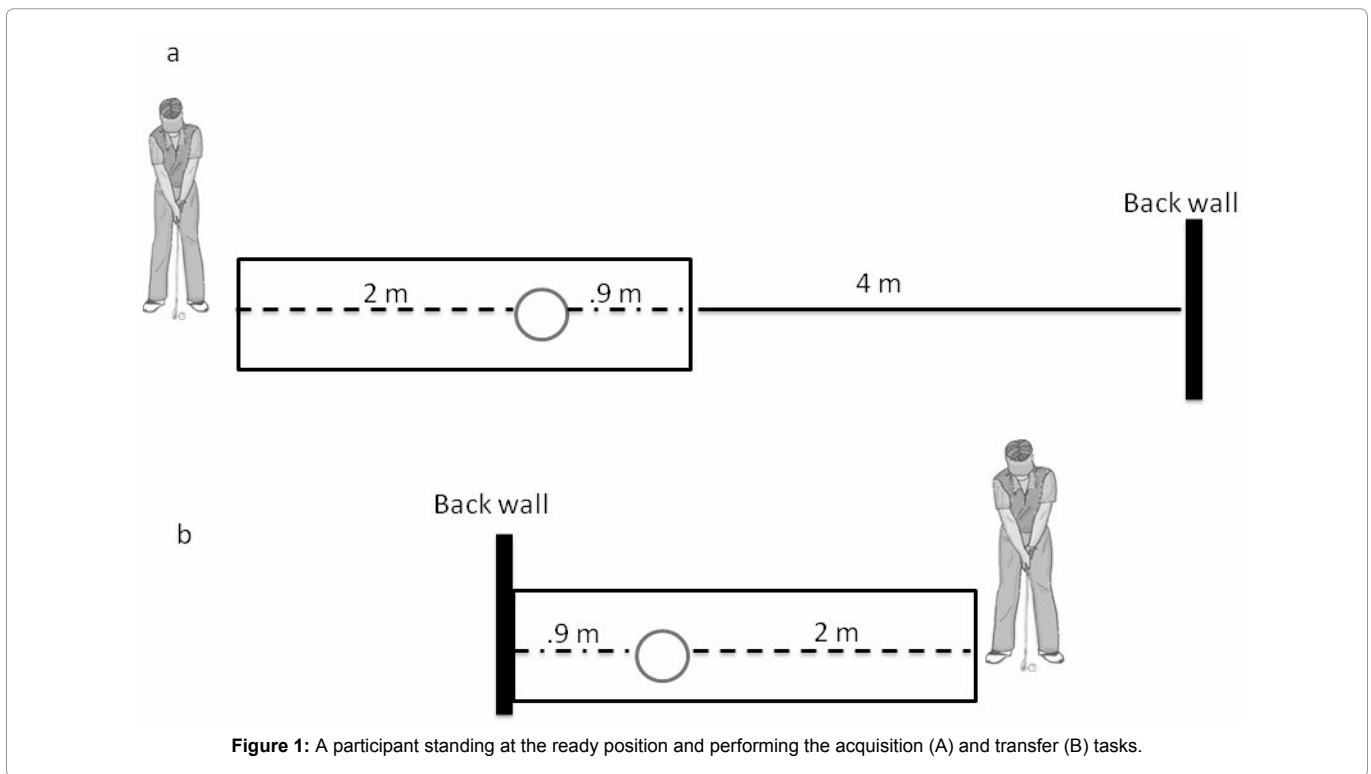


Figure 1: A participant standing at the ready position and performing the acquisition (A) and transfer (B) tasks.

### Acquisition task

The acquisition task consisted of performing a golf putt from a distance of two m on a 1m x 4m 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 drawn on the grass; the distance between the hole and the back wall was 4 m. The distance between the point where the ball landed and the center of the hole was measured in centimeters and recorded for each putt. In addition to the distance from the center of the golf hole, the circle around the target was virtually divided into 12 30° sections (like the 12-hour dial of a clock), and the angle the ball landed from the target was measured in order to calculate the X and Y coordinates of the ball. This, in turn, allowed for the calculation of variable error (VE; see section on dependent variables).

### Transfer task

The transfer task was the same as the acquisition task. However, before starting the task the participant turned around 180°, so that the wall in front of him (now the wall in back of the hole) 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. In addition, the 180° change allowed us to determine whether the task was learned relative to intrinsic coordinates (i.e., relative to one's own body) or relative to extrinsic coordinates (i.e., relative to the spatial arrangement). Whether learning occurs relative to intrinsic or extrinsic coordinates is of importance to those professionals who teach the foundations of a given motor skill – coaches, instructors, and physical education teachers. If, for example, a motor skill is learned relative to intrinsic coordinates, the learning environment is not that significant. In contrast, if a skill is learned relative to extrinsic coordinates, the environmental settings play a crucial role in learning,

and should be taken into account in the planning of a practice/training regime. Previous research has shown that transfer in learning appears to be related more to intrinsic coordinates than to extrinsic ones. For example, in one study on motor learning [23], transfer was recorded as good when participants performed the same joint displacements in two different (orthogonal) workspaces. In contrast, transfer was recorded as poor when joint displacements were different but hand position was similar. These results are supported by other studies focusing on transfer in learning [24,25].

Since the participants in our study were naive to the performed golfing tasks and did not have any experience in playing golf prior to their participation in the current study, we introduced only one new environmental variable to them in the transfer task, one they had not faced during the acquisition task – the distance between the target and the wall located at the back of the target. We did not want to expose the beginning golfers to dramatic changes in their learning environment, however it was one of our objectives to study their putting accuracy and gaze behavior in a learning condition that was varied from the acquisition condition – in this case only slightly different. We assumed that the environmental change that was made in the transfer task, although a small one, would require that the participants adapt to a new learning situation, and therefore changes in patterns of accuracy of performance and gaze behavior would follow.

### Instrumentation

Gaze was recorded using the Mobile Eye tetherless eye tracking system camera (Applied Science Laboratories, Bedford, MA, USA). The system is composed of lightweight (76g) head-mounted optics that are mounted on clear goggles. The head-mounted optics records the outside scenery as seen by the participant and the movement of the participant's pupil into a portable digital video cassette recorder

(Model GV-D1000, Sony Corporation, Tokyo, Japan). The sampling rate of both the gaze camera and the scenery camera is 30 Hz. The system uses the cornea reflection technique to calculate gaze positions. Gaze data were recorded directly into a laptop computer. The recorded videos were analyzed using Quiet Eye Solutions software (Quiet Eye Solutions, Inc., Calgary, Canada).

The computation of gaze positions was accomplished by comparing the vector between the pupil (which moves as the eye turns) and the reflection from the cornea (which remains in approximately the same position). The recorded videos (scenery and eye) were interwoven to produce one video showing the outside scenery, with a reticle representing the gaze position of the participant. The reticle size showing the direct gaze was set at 3° of the visual angle in order to accommodate the definition of QE. The participants wore the eye tracker throughout both phases of the study.

### Coding phases of the putt

Four phases of the golf putt were coded: (1) the preparation phase – from the moment the participant completed positioning the golf ball until the beginning of arm movement, (b) the swing – from the moment the arms moved backwards while gripping the golf club to the moment immediately before contact with the ball, (c) the contact – the moment the golf club came in contact with the golf ball, and (d) the follow-through – from the moment the ball left the head of the club until the moment the ball stopped. Coding the motor phases of the putt did not require the use of an external camera, due to the fact that all codeable movements were recorded by the Mobile Eye camera.

### Coding the types of gaze control

According to the QE definition proposed by Vickers [1], data were coded within 3° of the visual angle. QE was coded as the last fixation on the ball or on the head of the golf club prior to the initiation of the backswing motion. These locations were selected based on previous research. For example, in a previous study [11], the QE was coded based on the last fixation on the top of the ball, the back of the ball, the putter head, or a location adjacent to the ball. The offset of the QE was set when the fixation on the ball or the head of the golf club ended. This was based on the moment when the golf ball or the head of the golf club left the 3° reticle of the gaze position.

### Video coding procedures

Videos from the Mobile Eye camera were analyzed using Quiet Eye Solutions software. The motor phases (i.e., preparation, swing, contact, and follow-through) were coded into the software by watching the videos of the golf putts frame-by-frame. After the motor phases were coded, the count and duration (in msec) of gazes were coded on the videos frame-by-frame (each frame=33.3 msec). The QE duration was calculated automatically by the software using the last fixation that began before the defined critical movement (i.e., the swing), and that lasted at least 100 msec. All coding in this study – coding of both gaze behavior and visual coding – was performed by one experimenter (the first author).

### Procedure

The study was composed of two phases: Phase 1, which took place on Days 1, 2, and 3, and Phase 2, which took place on Day 4. Two to four days elapsed between each of the four days of testing. Since a novel task was selected in the current study, it was our aim to provide

all the participants with the opportunity to practice the golf task under normal (quiet) conditions (Phase 1) prior to their exposure to the distracted conditions (Phase 2).

### Phase 1 – Quiet conditions (acquisition, retention, and transfer)

#### Acquisition (Days 1 and 2)

On Day 1, upon arrival at the Motor Behavior Laboratory, the participants were provided with a general description of the experiment and detailed information on the testing procedures. The participants 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 length of instructional provision was about six min. After the instructions were provided, a self-report questionnaire was given to each participant to complete, in order to assess whether the technical instructions were understood correctly by the participant. The self-report questionnaire contained four questions on the techniques (i.e., how to hold the club and how to swing) of the task. All participants successfully completed the questionnaire.

After completion of the self-report questionnaire, each participant was given 20 trials for practice. The participants were asked to practice their stance and holding the golf club. The practice session lasted about three min. Testing began after the practice session was completed. The Mobile Eye gaze tracking system was fitted onto the participants and calibrated to at least five different locations, based on the manufacturer's instructions. The calibration points were placed around the golf ball. After calibration was obtained, the gaze position accurately showed both the ball and the target. The calibration procedure for a number of the participants was not successfully completed, and therefore these participants were dropped from the study. Those individuals who were dropped from the study were replaced by new participants, who underwent the same introductory procedures.

Each participant then performed the golf-putting task for six blocks of 10 trials, with a rest interval of two min between blocks. The number of the blocks and trials was selected based on pilot data, which revealed that a plateau in performance was reached after the sixth block (each block was composed of 10 trials). Gaze data were recorded continuously throughout the putting in order to prevent drifts in calibration. Twelve trials were randomly chosen (two from each block) for analysis of gaze control data. Randomization was accomplished using a computerized random number generator. Performance accuracy and consistency were recorded for all trials. In participants for whom the gaze recording was not stable, the best and most stable recorded putts were selected. The same procedure used on Day 1 was also used on Day 2. In total, each participant completed 120 trials of the golf putting task in acquisition. Calibration was rechecked after every three blocks at the beginning of each task (i.e., retention, transfer), and then, whenever needed, the system was recalibrated.

#### Retention and transfer (Day 3)

Retention and transfer took place on Day 3. Upon arrival at the Lab, participants were re-fitted with the Mobile Eye system, and calibration to at least five different locations was performed. In the retention task, participants performed the same golf-putting task as the one they performed in the acquisition task, for two blocks of six trials, with a two-min rest between each block. The same procedure



was applied in the transfer task: it was performed in two blocks of six trials, with a two-min rest between each block. For the retention and transfer tasks, two random trials from each block were used for analysis of the gaze control data.

### Phase 2 – Quiet and distracted conditions (Day 4)

The retention and transfer tasks were repeated in Phase 2. The retention task was performed in two blocks of six trials, with a two-min rest between each block, and the transfer task was also performed in two blocks of six trials, with a two-min rest between each block. Since a low number of trials should be performed in the conditions of retention and transfer compared with the number of trials in acquisition [3,22], we asked the participants in the retention and transfer conditions to putt the ball at the hole 12 times. We provided them with a break after Trial 6 in order to analyze the block effect as well. However, in Phase 2, 12 participants performed these tasks under quiet conditions and 12 participants performed the task under audio distractions (distracted conditions). The audio-distraction participants performed the tasks while noisy sounds were played on a portable CD player at 85 dB. Noises included the sound of drums and other percussion instruments, the clattering of moving railroad wheels, and hammer blows in a metalworking shop. The noises were sounded continuously while the participants performed the tasks. A volume of 85 dB was chosen, as this volume is safe to listen to for short periods of time [26]. Noise and not visual distractions was selected for the experiment, as it is more likely that audio distractions will be present in the golfer's environment, since there usually are no visual distractions in the relatively small visuo-motor workspace when putting.

### Dependent variables

Four variables of the putting performance were measured: (a) absolute error (AE) – a measure of overall accuracy in performance: the distance the ball landed from the target for each shot, without regard to direction; (b) variable error (VE) – a measure of consistency which assesses the spread of the hits around the mean location of the hits [27], which is calculated by using the X and Y coordinates of the location of where the ball lands in relationship to the hole; (c) bull's-eyes (i.e., hitting the golf target); and (d) QE duration.

### Statistical analyses

For Phase 1, a one-way ANOVA with repeated measures was performed separately on the AE, VE, and QE variables across acquisition, retention, and transfer (Acquisition – Day 1, Acquisition – Day 2, Retention and Transfer – Day 3). For Phase 2, a two-way ANOVA (Noise x Stage of Learning) with repeated measures on the last factor was performed separately on the AE, VE, and QE. Fisher Least Significant Difference (LSD) was used as a post-hoc procedure, where appropriate. Effect sizes ( $\eta^2$ ) were reported when needed. To examine the association between QE, AE, and VE, correlational analyses were performed. Alpha was set at .05 for all statistical tests.

## Results

Results are presented separately for Phase 1 (acquisition, retention, and transfer tasks) and Phase 2 (retention and transfer tasks).

### Phase 1

**AE, VE, and QE across acquisition, retention, and transfer:** The calculated values for AE, VE, and QE across the three stages of

learning – acquisition, retention, and transfer, and the significant values of the statistical analyses, are presented in Table 1. For AE, the one-way ANOVA revealed significant differences between acquisition, retention, and transfer,  $F(2.08, 47.74)=12.57, p<.001$ , partial  $\eta^2=.35$ . The results were significant in both the traditional  $F$ -values and the conservative degrees of freedom adjustments [28]. As indicated in the post-hoc analysis, AE was lower (better) in the transfer than in both acquisition (Day 1) and retention.

For VE, the one-way ANOVA revealed significant differences between acquisition, retention, and transfer,  $F(3, 54)=13.38, p<0.001$ , partial  $\eta^2=0.43$ . The post-hoc analysis indicated that VE was lower (better) in the transfer than in Day 1 of acquisition, Day 2 of acquisition, and retention.

No significant differences between acquisition, retention, and transfer were found in QE.

### Correlational relationship between QE, AE, and VE

Low to moderate negative correlations were found between QE and AE (Day 1:  $r=-0.35, p=0.07$ ; Day 2:  $r=-0.37, p=0.08$ ; retention:  $r=-0.53, p=0.008$ ; transfer:  $r=-0.29, p=0.17$ ), and between QE and VE (Day 1:  $r=-0.30, p=0.2$ ; Day 2:  $r=-0.44, p=0.06$ ; retention:  $r=-.60, p=0.006$ ; transfer:  $r=-0.51, p=0.02$ ).

**Bull's-eyes:** A small number of shots landed in the circle on the grass mat: out of all the shots in each stage, only 2.7-3.8% did so. Due to this small number of bull's-eyes, only descriptive statistics are presented for them.

**Phase 2:** In Phase 2, the 24 participants were randomly assigned into two groups: (a) a quiet condition, and (b) an auditory distracting condition. Each participant performed two sets in retention and two sets in transfer. Table 2 presents the data for AE and VE during retention and transfer and under quiet and noisy conditions. For AE, the two-way ANOVA revealed a main effect for noise,  $F(1, 22)=4.69, p=.042, \eta^2=.18$  and a main effect for stage (retention/transfer),  $F(1, 22)=10.77, p=.003, \eta^2=.33$ . AE was higher (e.g., lower performance) under noisy conditions ( $29.68 \pm 7.84$  cm) compared to quiet conditions ( $23.64 \pm 5.68$  cm; higher performance). In addition, AE was higher during retention ( $29.78 \pm 8.22$  cm) compared to transfer ( $23.53 \pm 9.10$  cm). For VE, the two-way ANOVA revealed a main effect for stage (retention/transfer),  $F(1, 17)=7.79, p=.013, \eta^2=.31$ : VE was higher during retention ( $35.11 \pm 9.09$  cm) compared to transfer ( $27.89 \pm 10.56$  cm).

A Noise x Stage (retention/transfer) interaction was found for QE duration [ $F(1, 22)=6.53, p=.018, \eta^2=.23$ ]. QE duration was similar in retention under both quiet and noisy conditions ( $1,236.77 \pm 385.75$  msec and  $1,244.22 \pm 476.48$  msec, respectively). However, during transfer, QE duration was longer in the quiet ( $1,361.85 \pm 448.14$  msec) compared to the noisy ( $984.92 \pm 359.34$  msec) condition [ $t(22)=2.27, p=.03, ES=.84$ ].

### Correlational relationship between QE, AE, and VE

**Retention:** Under quiet conditions, low to moderate inverse correlations were found between QE and AE ( $r=-0.31, p=0.33$ ) and between QE and VE ( $r=-0.49, p=0.26$ ). However, no correlations were found under noisy conditions (QE and AE:  $r=-0.10, p=0.77$ ; QE and VE:  $r=-0.18, p=0.58$ ).

**Transfer:** Under quiet conditions, the correlation between QE and AE was low ( $r=-0.17, p=0.59$ ), but it was high between QE and

**Table 1:** AE, VE, and gaze data during Phase 1 of the study (Means ± SD).

	Acquisition Day 1	Acquisition Day 2	Retention	Transfer
AE (cm)	32.74 ± 8.34	25.78 ± 6.94#	30.11 ± 8.57	23.33 ± 7.49##
VE (cm)	39.25 ± 9.67	32.76 ± 7.04*	34.57 ± 7.18	28.10 ± 6.91**
QE (msec)	1,293.14 ± 399.61	1,279.59 ± 379.41	1,264.49 ± 382.30	1,214.20 ± 349.05

# Significantly different from Acquisition Day 1 ( $p < 0.001$ ) and from Retention ( $p = 0.014$ ).

## Significantly different from Acquisition Day 1 ( $p < 0.001$ ) and from Retention ( $p < 0.001$ ).

\* Significantly different from Acquisition Day 1 ( $p = 0.001$ ).

\*\* Significantly different from all other stages ( $p < 0.001$ ).

**Table 2:** AE and VE during Phase 2 of the study (Means ± SD).

	Quiet Conditions		Noisy Conditions	
	AE	VE	AE	VE
Retention	26.63 ± 7.15	33.01 ± 8.56	32.94 ± 8.25	36.33 ± 9.54
Transfer	20.65 ± 6.62	25.06 ± 6.47	26.42 ± 10.55	29.54 ± 12.31
Total	23.64 ± 5.68	29.04 ± 8.37	29.68 ± 7.84*	32.94 ± 11.31

\*Significantly different from AE under Quiet Conditions ( $p = 0.04$ ).

VE ( $r = -0.79$ ,  $p = 0.04$ ). Under noisy conditions, moderate inverse correlations were found between QE and AE ( $r = -0.51$ ,  $p = 0.09$ ) and between QE and VE ( $r = -0.58$ ,  $p = 0.05$ ).

**Bull's-eyes:** Participants achieved bull's-eyes more often during the quiet condition (retention: 6, transfer: 8 bull's-eyes) compared to the distracting condition (retention: 0 bull's-eyes; transfer: 4 bull's-eyes). As indicated before, due to the small number of bull's-eyes, only descriptive statistics are presented.

## Discussion

We assumed in the current study that those participants who demonstrated longer QE durations would be more accurate and consistent in their putting performances than those who exhibited shorter QE durations. It was also assumed that performance would deteriorate, and QE would be shorter, under distracted (noisy) conditions.

The assumptions we made were partially supported by the data. First, the presence of noise led to increased AE (i.e., reduced accuracy) but not to increase VE. Second, QE durations were lower under noisy conditions compared to quiet conditions in the transfer test but not in the retention test. Third, moderate inverse correlations were found between QE and AE and between QE and VE in most stages of the study. In addition, it was found that golf-putting performances improved in the transfer test compared to both the acquisition and retention tests.

### Distractions, performance, and QE

Only AE was negatively affected by the distracted (noisy) conditions. This finding suggests that accuracy is prone to deteriorate in the presence of audio distractions. The interaction in QE duration between stage (retention and transfer) and noise (yes/no) suggests that the presence of audio distractors was also related to a significant reduction in QE duration during the transfer test (~980 msec), and these relatively low QE values could have contributed to the reduced accuracy. However, this interaction also suggests that the distance of the wall from the golf hole may be a factor that affected QE duration as well. In the retention test, when the back wall was over four meters away from the hole, no difference in QE duration was found. However, in the transfer test, when the wall was only 90 centimeters behind the hole, the presence of audio distractors led to reduced

QE durations. From the data in the current study, it is unclear why reduced QE durations were not found in the retention test as well, and this should be examined in future studies.

It is not surprising that inverse correlations were found between both QE duration and AE and QE duration and VE. Indeed, the beneficial role of a long QE duration in the performance of closed, self-paced tasks has been emphasized in the literature for over 20 years. In most stages of our experiment, correlations were moderate to high. However, in Phase 2, under noisy conditions in the retention stage, correlations were low ( $r = -0.1$  and  $-0.18$  for AE and VE, respectively). These values were much higher during the transfer stage ( $r = -0.51$  and  $-0.58$  for AE and VE, respectively). It is unclear why these differences existed. However, it is possible that the first appearance of noise in the retention stage had a greater distracting impact on the participants, and that while they fixated on the ball their attention was directed to the noise.

The fact that auditory distractors can negatively affect the performance of a self-paced motor skill is of importance to athletes, since they regularly perform in front of noisy fans. For example, a basketball player who stands at the free-throw line must be able to disregard the noise generated by the fans. It should be noted that the noises presented in the current study and in previous studies [29] do not represent the actual noises that athletes usually encounter. It was our objective in the current study to enable the participants to perform the golfing task in unfamiliar distracted conditions with noises that were not connected to the golf environment. In future research, an ecological approach should be adopted in terms of the selection of more authentic and real-life distractions – both visual and auditory – that athletes may actually encounter in practice sessions and competitions/games.

### Improved performance in the transfer task

In both Phase 1 and Phase 2 of the study, AE and VE were lower in the transfer task compared to both the acquisition and retention tasks. This is a somewhat surprising finding, since the transfer task provided a new version of the learned golf-putting task – namely that the participants had to turn 180° and consequently face a wall at a different distance from that in the acquisition and retention tasks. Generally speaking, it is assumed that under transfer settings the accuracy of performance either remains the same or deteriorates [30].

The data of our study do not support this assumption; in fact, the participants were more accurate in the transfer task than in either the acquisition or the retention tasks.

One possible explanation for the improved performance in the transfer task is that the inexperienced participants used the transfer trials for learning. One can argue that although the putting task performed in the transfer condition indeed differed from the putting task performed in acquisition and retention (i.e., the distance of the wall behind the target), the two tasks still shared a number of similar characteristics (e.g., the same club and ball, the size of the hole, the distance of the performer from the hole, the task's goal, and the spatial location of the target). It is suggested that while performing the transfer task the participants were already familiar with the main features of the task, and therefore could manage – both physically and psychologically – to perform in a condition where only one environmental cue (e.g., the distance of the wall behind the target) was new to them. Most likely they were not anxious while facing the transfer task, and therefore were able to improve their accuracy of performance. It was argued by Schmidt and Lee [30] that the greater the similarities between the acquisition task and the transfer task, the higher the achievement of success in the transfer task.

However, it is unlikely that the improvement of the putting accuracy in the transfer task was due only to learning, considering the fact that the participants also performed 12 trials in the retention task and did not improve their accuracy in that task. In fact, a few minutes after completing the retention task they performed another 12 trials of the transfer task, with significantly better results. It would probably be imprecise to attribute such a difference solely to the learning experience. To account for the improved performance in the transfer task in both Phases 1 and 2, we offer a speculative explanation associated with the information used by the participants when performing the task in the varied conditions of the putting task. As indicated before, the transfer task required participants to perform the same golf putt as in the acquisition and retention tasks, but with a change in direction of 180°. The idea was to examine whether learning occurred based on intrinsic coordinates (in which case no change in performance was to be expected), or based on extrinsic coordinates (in which case some change in performance was expected). In both the acquisition and retention tasks, the placement of the artificial grass provided approximately four m of open space behind the hole at which the participants were aiming. In contrast, in the transfer task, when the participants turned 180° and were facing the other side of the room, there was only about 90 cm of space covered by artificial grass behind the hole. It has been suggested that novices are more reliant on environmental information (i.e., learning relative to extrinsic coordinates) and less on body-centered information (i.e., learning relative to intrinsic coordinates) [31]. Therefore, it may be possible that the improved performance in the transfer task was due to the novel environmental stimulus that provided a better sense of depth (i.e., the presence of the wall 90 cm behind the hole), and therefore allowed for better control of the velocity of the golf club. This explanation should be further examined in future research.

The participants who took part in our study were novices in golf and did not have any experience playing this sport. Indeed, since they were not familiar with the golfing task, we were able to examine the accuracy of performance and gaze behavior in a truly novel task. However, the inclusion of novice participants may have limited the findings of the current study due to the fact that novices are still learning the task, and may be subjected to more constraints that impact upon the stability of their gaze behavior [1]). Among

these constraints are the low skill level of the participants, the unique characteristics of the golfing task (e.g., aiming at a small-size target and controlling the power production of the involved muscles), and the environment (e.g., the distance between the performer and the hole). It is assumed that different patterns of gaze behavior would be demonstrated by participants who are experienced in playing the game of golf.

In the current study, the order of Phases 1 and 2, as well as the acquisition, retention, and transfer of the golfing task, were fixed for all participants. The reason for the selection of this order was that we aimed at providing the beginning participants with optimal learning conditions where they were able to practice the unfamiliar golf task. The participants first practiced the skill in a sterile learning environment, then performed the skill in a transfer setting, and only then were asked to perform under a distracted condition. 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, in order to effectively control the presentation of the distracted variable.

While the findings that emerged from the current study showed that noise can have a negative effect on performance, more evidence is required in order to increase the level of proof. In this respect, future research should use different types of auditory and visual distractions. These distractions should be ecologically valid and mimic the actual distractions athletes face in competitive settings (e.g., crowd noise, distracting opposing players). In addition, the influence of QE training on performance under distracting conditions should be examined. Indeed, it has been shown that QE training can improve the performance of targeting skills under both normal and anxious conditions (for a review, see [9]). However, this finding should be supported in experimental settings that are composed of external distractions.

In conclusion, based on the data of this study, we suggest that future studies (a) examine the contribution of gaze behavior to achievement in closed, self-paced tasks performed under distracted conditions – specifically, whether maintaining QE durations or training for longer QE durations can prevent deterioration in performance in distracted conditions; (b) match the type of distractors to those common in the environment where the self-paced tasks are actually performed; and (c) examine whether different external settings (e.g., in our study, the presence of the wall at a closer distance behind the target) can affect the performance of self-paced tasks.

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