EFFECT OF BINOCULAR VS. MONOCULAR VIEWING ON GOLF PUTTING ACCURACY

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Abstract

The purpose of this experiment was to study the role of binocular vision, including both stereopsis and binocular vergence, on the complex task of golf putting. The putting accuracy of 16, visually-normal, inexperienced golfers (range 23-66 years, mean=35 years) was assessed for small (3cm) and large (12cm) targets located at 3, 6, and 9 feet with their distance corrective lenses in place. Subjects performed the task under either normal binocular or monocular viewing conditions. Putting accuracy (% successful putts) was significantly better under binocular versus monocular viewing conditions for the smaller target. This was true for 10 out of 12 (83%, p=0.019), 11 out of 12 (92%, p=0.003), and 12 out of 12 (100%, p<0.001) of the subjects for the 3-, 6-, and 9-foot test distances, respectively. The percentage improvement in putting accuracy under binocular as compared to monocular viewing conditions for the small (3cm) target was 14%, 8%, and 13% for the 3-, 6-, and 9-foot target distances, respectively. For the larger target, the trends were similar but smaller in magnitude (0.5-7%) and not statistically significant. These findings are consistent with earlier studies demonstrating improved athletic performance under binocular versus monocular viewing conditions. The additional depth-related cues provided by stereopsis and binocular vergence appear to be crucial for more precise and detailed tasks, such as were present with the smaller target.

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Key Words

binocular vision, distance judgment, golf putting, stereopsis, vergence, visual field

INTRODUCTION

The sport of golf is a popular leisure activity for people of all ages. Arguably the most important aspect of golf is the "short game," that is, one's performance at and around the green. This is evidenced by both amateurs and professionals alike expending as many as 50% of their strokes on the putting green.[1]

Putting is a complex sensorimotor task requiring synchronized input from numerous physiological systems for successful execution. It represents an exciting area of study that has sparked interest in a diverse field of researchers and clinicians.[2-8] For example, recent work has demonstrated that novice golfers perform more poorly when speed versus execution is stressed.[2] Skilled golfers demonstrated the opposite effect. The authors reasoned that the additional time was useful for amateurs to prepare themselves, while that same time interrupts the proceduralized and reflexive skill of the experts.

Utilizing electroencephalography (EEG), researchers have found differences in cortical activity between novice and experienced golfers during the golf putt.[3] The EEGs of expert golfers demonstrated greater stimulation of the fronto-midline and parietal regions than did their novice counterparts. The investigators concluded that experienced golfers develop specific strategies for solving the golf putting task. These strategies include focused attention and reduced reliance on parietal area sensory information processing. Such strategies serve to improve task performance in experienced golfers. Other research has examined the role of different forms of anxiety on golf putting performance.[4] Cognitive anxiety (pressure to achieve) resulted in a negative linear relationship with performance, while self confidence intensity level manifested a positive linear relationship.

Another study has investigated the importance of various putter stroke factors on performance.[5] It revealed that face angle was the most important factor followed distantly by putter path and impact point. Furthermore, that variability in stroke direction for elite golfers was small enough to execute 95% of 4 meter (m) putts successfully.

Other recent studies have also explored the importance of the visual system in golf putting. For example, Hung et al found that presbyopic individuals demonstrated significantly increased head movement concurrent with some increase in eye movement when wearing narrow corridor versus wide corridor progressive addition lenses.[6] This suggested that blur and/or optical distortion were undesirable during putting. To further investigate the defocus blur aspect of that study, Bulson et al investigated the role of retinal defocus on golf putting and showed that performance was adversely affected only at very high (+10.00D) magnitudes of induced blur.[7] These studies reveal the role of retinal defocus that can result either from presbyopia or inappropriate refractive correction. In the context of the golf putt, the importance of the binocular vision system in such a task has not been explored.

Previous research has investigated athletic performance under binocular versus monocular viewing conditions. Von Hofsten et al found improved success in a ball catching activity under binocular viewing conditions as compared to its monocular counterpart.[8] The improvement under binocular viewing conditions was attributed to the additional information provided by binocular convergence that subjects used to scale perceived space. Similarly, Savelsbergh and Whiting demonstrated that skilled subjects had an increase in spatial errors for a one-handed ball catching task under monocular conditions as compared to binocular viewing.[9] More recently, Mazyn et al showed that subjects with poor stereopsis performed equally at catching tennis balls under binocular and monocular viewing conditions; however, those with good stereopsis performed better binocularly than monocularly.[10] Furthermore, these effects were more pronounced as the ball speed increased. This suggests an increased role of binocular vision under more complex high speed, dynamic conditions. Thus, it is clear from these experiments that binocular vision is important in a variety of dynamic ball catching tasks.

The purpose of the present experiment is to elucidate the role of binocular vision, including both stereopsis[11] and binocular vergence information,[12] in the complex task of golf putting at a range of distances.

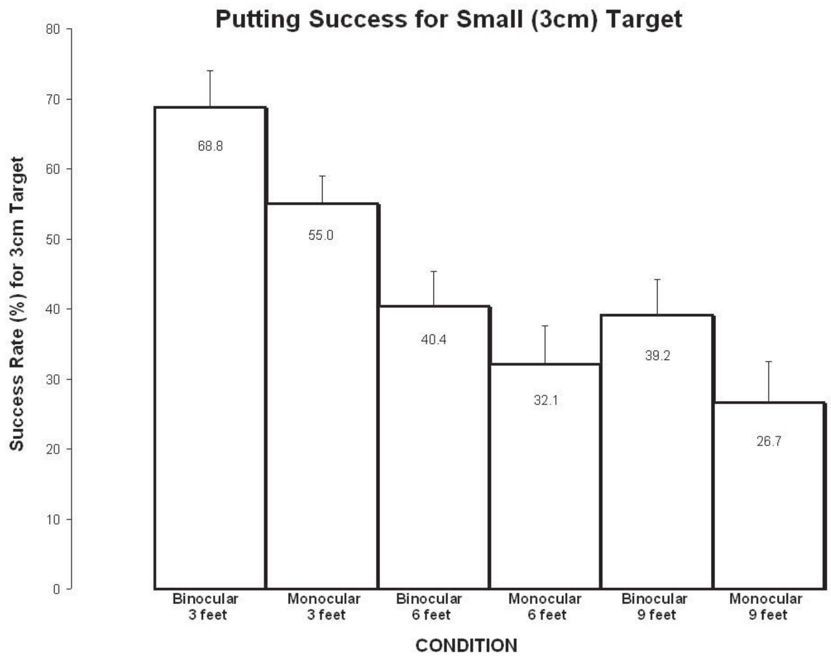

Figure 1. Putting accuracy (% successful putts) as a function of the viewing condition for the smaller (3cm) target. Plotted is the group mean +1 SEM.

METHODS

Subjects

Twelve novice adult golfers ranging in age from 23-66 years (mean=35 years) were recruited from the State University of New York, State College of Optometry (students and faculty). Five of the subjects were male, and 7 were female. Each reported having normal binocular vision (stereoacuity ≤40 arc seconds), were free from any ocular or neurological disease, and were visually asymptomatic. None were taking any medications that could adversely affect either the oculomotor system or general motor control. All subjects wore their optical correction and were fully corrected to 20/20 or better in each eye with their distance prescription through either spectacles or contact lenses. All subjects signed consent forms and the study was approved by the College's Institutional Review Board.

Putting Green Design

A mock putting green composed of artificial turf 3.45m long by 1.80m wide was utilized to simulate the putting green.[7] The target was a standard computer compact disc (CD). The 3cm diameter center circular area of the CD approximated the size of a standard golf ball (4.4cm). The entire CD itself (12cm) approximated the standard cup diameter (10.5cm). The luminance of the ball, the putting green, and the CD target were $42cd/m^2$, $1.6cd/m^2$ and $2.5cd/m^2$ respectively, which approximated actual golf course conditions on a cloudy day. The contrast of the ball and the contrast CD target on the putting green was 93% and 22%, respectively. All trials were conducted under standard room illumination.

Procedure

At the beginning of the experiment, subjects practiced putting binocularly at each of three target distances: 3 feet, 6 feet, and 9 feet. This involved 15 putts at each distance. Following this practice session, subjects executed 20 consecutive putts to the disc target located at each of the above distances under binocular and monocular viewing conditions. All putted right handed. A black eye patch was placed over the right eye for the monocular testing. Initial target distance and viewing status were tested in a counterbalanced manner. The percentage of successful putts for both the small and large targets was computed for all test conditions.

A putt was considered successful for the small target if at least one half of the ball touched the center hole portion of the CD, and the speed of the putt was such that it would have been judged to have entered a real golf cup. Likewise, the putt was considered successful for the large target if at least one half of the ball touched anywhere on the CD, and the speed was such that it would have been judged to have entered a real golf cup.

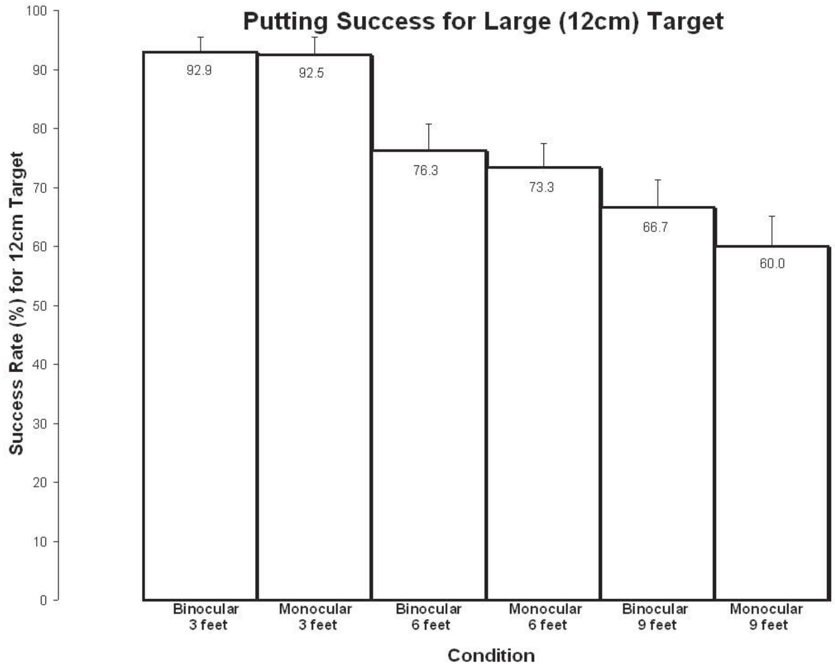

Figure 2. Putting accuracy (% successful putts) as a function of viewing condition for the large (12cm) target. Plotted is the group mean +1 SEM.

RESULTS

The group findings for the 3cm target are presented in Figure 1. A two-way ANOVA was performed using the factors of target distance (3, 6, and 9 feet) and viewing condition (binocular versus monocular). They were significant for both viewing condition [F (1, 11) =63.27, p=0.000007] and target distance [F (2, 22) =22.60, p=0.000005]. A post-hoc Fisher least significant difference test was performed. All critical comparisons, mainly binocular versus monocular viewing at each distance, were significant (p=0.0017 for 3 feet, p=0.0415 for 6 feet, and p=0.0037 for 9 feet); hence, putting accuracy was better under binocular viewing conditions. The percentage improvement in putting accuracy was approximately 14%, 8%, and 13% for the 3-, 6-, and 9-foot target distances, respectively for binocular vs. monocular viewing. Lastly, the number of subjects who performed better binocularly versus monocularly was compared using the binomial test. Ten out 12 (83%, p=0.019), 11 out of 12 (92%, p=0.003), and 12 out of 12 (100%, p<0.001) performed better binocularly for the 3-, 6-, and 9-foot test distances, respectively.

Figure 2 provides a summary of the group results for the 12cm target. Statistical analysis was performed as for the 3cm target. The two-way ANOVA results for viewing condition (binocular vs. monocular) [F (1, 11) =52.47, p=0.000017] and target distance (3, 6, and 9 feet) [F (2, 22) =16.10, p=0.000049] were significant, but post-hoc analysis revealed no significant differences for the critical comparisons between binocular versus monocular viewing for each distance (p=0.925 for 3 feet, p=0.511 for 6 feet, and p=0.141 for 9 feet). The percentage difference in putting accuracy between binocular and monocular viewing was approximately 0.5% for 3 feet, 3% for 6 feet, and 7% for 9 feet. The number of subjects performing better binocularly than monocularly was 7/12 (58%, p=0.38), 9/12 (75%, p=0.073), and 9/12 (75%, p=0.073) for 3, 6, and 9 feet, respectively, thus suggesting a similar binocular improvement.

DISCUSSION

The findings of the current experiment suggest that binocular vision is advantageous when performing a complex sensorimotor task, such as golf putting. This is especially true under the more stringent putting condition with the smaller target. Binocular vision gives rise to the phenomenon of stereopsis; this is the ability of the visual system to use horizontal retinal-image disparity information to contribute to the overall perception of relative depth and three-dimensional shape.[13] Stereopsis as the mechanism for improved athletic performance under binocular versus monocular viewing conditions is supported by several earlier studies.[10,14] For example, Lenoir et al investigated the role of stereopsis in a one-handed ball catching technique.[14] Subjects with either "good" (≤40 arc sec on the Titmus test) or "poor" stereopsis (≥120 arc sec on the Titmus test) performed the task under binocular viewing conditions. There was only a trend for subjects with good stereoscopic vision to be more successful at the task. The authors attributed the better than expected performance of the subjects with poor stereopsis to compensatory mechanisms established by these individuals, such as stronger reliance on, or more weighting of, monocular depth cues. Furthermore, with the exception of a single subject having only monocular vision, the investigators noted that all subjects exhibited some degree of stereopsis. Thus, with one exception, both groups of subjects had access to retinal disparity and correlated depth information, but were sensitive to this information to different degrees. However, they purported that the small difference in performance between subjects with "good" versus "poor" stereopsis may translate into the difference between an average player and an excellent player in athletic competition. Mazyn et al performed a similar one-handed ball catching experiment under both monocular and binocular viewing conditions. They used three different ball velocities as previously discussed in the present paper.[10] Subjects were divided into two groups, stereo "normal" (≤40 arc sec) and stereo "weak" (≥400 arc sec). Stereo "normal" subjects performed significantly better under binocular versus monocular conditions, whereas no difference in performance was observed in the stereo weak subjects. These trends were more pronounced as the velocity of the ball increased, namely under more demanding dynamic test conditions. These findings are in agreement with those of the current study that binocular performance is superior to monocular performance in golf putting. Interestingly, the Mazyn et al stereo weak group did not perform better under binocular viewing conditions, despite the presence of monocular cues from the viewing eye. Further, stereo normal subjects performed significantly better than stereo weak subjects under binocular viewing conditions, in contrast to the findings of the Lenoir et al study.[14] Their findings suggest that loss of stereopsis could account, at least in part, for the difference in performance under monocular versus binocular viewing conditions in the present study.

Another possible explanation for the improvement in putting accuracy observed under binocular versus monocular viewing conditions is information related to binocular vergence angle, such as proprioception, kinesthetic awareness, and perhaps vergence innervation. Binocular vergence can provide important information regarding the relative distance of objects in one's visual environment. Von Hofsten demonstrated that subjects had different, but consistent, levels of tonic vergence.[12] Furthermore, their perceived distance from an object was related to the difference between their unique tonic vergence and target convergence demand. The author concluded that the simplest explanation was the kinesthetic awareness related to the specific convergence demand relative to the tonic vergence level. Thus, kinesthetic cues are likely a major stimulus for distance perception via the binocular vergence system, especially for smaller disparities.

As previously cited in this paper, von Hofsten et al investigated the role of binocular vision in a one-handed ball catching task.[8] Subjects were asked to complete the task under both monocular and binocular viewing conditions in either an illuminated room or in a completely dark room with an illuminated ball. The authors hypothesized that binocular vergence information would be the only cue for judgment of distance in the dark room. Therefore, catching the ball should be significantly better under binocular versus monocular conditions in the dark room. They further reasoned that this discrepancy in performance between monocular and binocular viewing should be less marked in the illuminated room where cues other than binocular vergence could be employed to establish perceived distance. The results of the experiment revealed a greater performance advantage binocularly under the illuminated versus dark conditions. These findings suggested that depth perception by means of binocular vergence information requires an externally defined binocular reference point. Tonic vergence level alone was not adequate in calibrating binocular vergence with respect to perceived depth. Thus, in the present study, it is possible that golf putting performance was significantly reduced under monocular versus binocular viewing conditions due to lack of such binocular vergence information related to perceived distance.

Factors other than the absence of stereopsis and binocular vergence information may have also contributed to the poorer performance under monocular viewing conditions in this study. A significant side effect of the eye patch was a reduced field-of-view. Recent work demonstrated a reduction in both the speed and accuracy of a complex obstacle course maneuvering task as the field-of-view was reduced.[15] Furthermore, Wu et al suggested that relatively large regions of the ground surface are required for accurate distance judgments.[16] Therefore, restrictions in one's field-of-view may result in an underestimation of target distance. In the present study, the observers' field-of-view was severely restricted by the eye patch, such that their ability to properly estimate target distance may have been impaired to some extent.

Additional Considerations

Numerous studies comparing task performance under monocular versus binocular viewing conditions have been published.[8-10] A significant criticism of these papers was the use of an eye patch to eliminate stereoscopic vision. It is important to consider that, in addition to the elimination of stereopsis, monocular viewing also reduces monocular depth cues from the occluded eye; these include shadow, retinal expansion of an approaching object, and parallax.[14] It would be extremely difficult experimentally to eliminate stereopsis without disrupting such retinal information of one eye under conditions conducive to golf putting. Another important point that was raised by Savelsbergh and Whiting was the fact that visually-normal individuals habitually navigate through the world in a binocular fashion.[9] As such, one would expect improved performance of most tasks under binocular conditions due to this chronic habituation process.

CONCLUSIONS

Adult novice putters demonstrated significantly better putting for the small target under binocular as compared to monocular viewing conditions. Likewise, there was a trend for improved putting scores for the larger target under binocular viewing conditions as opposed to that found monocularly. These results suggest that putting skill is better under binocular rather than monocular viewing conditions.

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